REPORT

Wakehurst Parkway Flood Mitigation Feasibility Study

Client:	Northern Beaches Council
Reference:	PA1943
Status:	0.2/Final
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Executive Summary

Northern Beaches Council (Council) engaged Royal HaskoningDHV (RHDHV) to undertake a flood mitigation options feasibility study to determine the appropriateness and effectiveness of proposed measures to mitigate very frequent flooding of Wakehurst Parkway.

The option feasibility assessment (reported herein) built upon an initial options assessment undertaken by RHDHV (RHDHV, 2018). The RHDHV (2018) report identified several options for flood mitigation and concluded with a shortlist of options requiring further assessment. The options were segregated across three geographical locations of the Wakehurst Parkway, namely in the vicinity of the Sydney Academy of Sports in the north, Oxford Falls Road junction in the south, and at a section of road referred to as 'The Bends', approximately part way between the two. These three locations were identified as most susceptible to over-road flooding and therefore formed the focus for flood mitigation options.

The options shortlisted by RHDHV (2018), and assessed further as part of this report, include those presented in the below table.

Option	Description
The Bends	
Option B1	*New levee*
Option B2	*New levee and removal of 1m depth of overbank sediment*
Option B3	*New levee, removal of 1m depth of overbank sediment and under-road culverts*
Option B4	*New levee, removal of 1m depth of overbank sediment, under road culverts, and top up of existing levee.*
Option B5	*Removal of overbank sediment (1m depth)*
Option B6	*Removal of overbank sediment (2m depth)*
Option B7	*New levee, under road culverts.*
Oxford Falls Road	
Option O1	*Culvert capacity increase*
Option O2	*Culvert capacity increase (additional to O1)*
Sydney Academy of Sport and Recreation	
Option S1	*Bunds and localised low point drainage*

Several additional assessments were commissioned by Council to inform this feasibility assessment. The additional assessments were undertaken concurrently and included:

- Geotechnical investigation;
- Acid Sulfate Soils and Contamination Assessment;
- Aboriginal Heritage Assessment;
- Further topographic survey; and
- Services search.

The flood mitigation options presented in the above table were assessed against key constraints. Each option was subject to the following assessment:

- Concept design;
- Planning and approvals assessment (environmental planning / permissibility);
- Constructability;
- Flood modelling;
- Cost estimation (all presented excluding GST); and
- Risk assessment.

The feasibility of each option is summarised in the below table.

<table>
<tr><th>Option</th><th>Description</th></tr>
<tr><td>*Option B1*</td><td>*New levee*</td></tr>
<tr><td colspan="2">***Overview***
The option is considered to be feasible, with the primary consideration the approval from NSW Roads and Maritime Services (RMS) for works within the road corridor. There would be a requirement for reduced travel speed limits during the anticipated 6-week construction period.

Flood Impacts
Flood impacts are minor positive, with some negative impacts at certain flood return periods. The option provides flood immunity up to 4 EY (3-month ARI).

Key constraints include space within the existing road corridor to implement the works, however this is expected to be achievable with minor road shoulder alterations and the need to limit working time, hence traffic disruption.

Environmental Impacts
The option presents little significant environmental impact, due to works being confined to the existing road corridor.

Estimated Capital Costs
The option is estimated to cost $2M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency), and could be implemented with relatively minor environmental impacts and approvals. No environmental offset costs are included.</td></tr>
<tr><td>*Option B2*</td><td>*New levee and removal of 1m depth of overbank sediment*</td></tr>
<tr><td colspan="2">***Overview***
In addition to Option B1, the sediment removal adds significant additional works outside the road corridor. The removal of overbank sediment does not require any physical works within the road corridor, however it would require significant road traffic management during mobilisation and demobilisations, as well as an estimated period of 6 weeks of truck movements. RMS approvals would be required. The construction timeline is anticipated to exceed 25 weeks, not including the revegetation maintenance period.</td></tr>
</table>

Flood Impacts

Flood impacts are moderate-positive, with some negatives. The option provides flood immunity up to 2 EY (6-month ARI). The addition of the sediment removal option reduces future risk of the flood situation being exacerbated through continued sedimentation.

Key constraints include access, traffic management, disturbance of existing valuable habitat and the need to dispose of excavated material.

Environmental Impacts

Environmental impacts are anticipated to be significant. There would be a direct impact to 2.88 ha of native vegetation and a further 0.45 ha of non-native vegetation would be impacted. Environmental offset costs estimated to be $670,000 (excl. GST).

The option is estimated to cost $5.8M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency), and the implementation would be subject to significant additional environmental assessment and approvals. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or an SIS, as well as a Biodiversity Management Plan.

Option B3	*New levee, removal of 1m depth of overbank sediment and under-road culverts*

Overview

In addition to Option B2 (new levee and floodplain sediment removal), the addition of under road culverts significantly increases the disturbance footprint, capital works and presents significant temporary road closure / partial closures. The option is considered to be constructible through open trench methods, whilst maintaining two-way traffic.

Environmental Impacts

Direct impacts due to sediment removal works, consist of direct disturbance to native vegetation and habitat of 2.41 ha. Indirect impacts to native vegetation and habitat of 0.22 ha (minimum) are estimated due to culvert works.

The disturbance to sensitive and valuable habitat east of the road by culvert tail out channels, as well as the sediment removal is anticipated to cause significant environmental impacts. There is an estimated environmental offset cost of $738,000 (excl. GST) for the option as a total.

Flood Impacts

Flood impacts are significant positive. The option provides flood immunity up to 1 EY (1-year ARI).

Estimated Capital Costs

The option is estimated to cost $12.1M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency), and the implementation would be subject to significant additional environmental assessment and approvals. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or an SIS, as well as a Biodiversity Management Plan.

Option B4	*New levee, removal of 1m depth of overbank sediment, under road culverts, and top up of existing levee.*

Overview

In addition to Option B3 (new levee, floodplain sediment removal and road culverts), the additional works associated with the existing levee 'top up' are considered relatively minor. Option B4 can therefore be considered similar to Option B3 in many aspects, whilst providing significant additional flood benefits.

Flood Impacts

Flood impacts are relatively significant positive. The option provides flood immunity up to 0.5 EY (2-year ARI).

Environmental Impacts

The disturbance to sensitive and valuable habitat east of the road by culvert tail out channels, as well as the sediment removal is anticipated to cause significant environmental impacts. There is an estimated environmental offset cost of $738,000 (excl. GST) for the option as a total.

Estimated Capital Costs

The option is estimated to cost $13.8M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency). Like Option B3, the implementation would be subject to significant additional environmental assessment and approvals. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or a SIS, as well as a Biodiversity Management Plan.

Option B5	*Removal of overbank sediment (1m depth)*

Overview

The option does not require any physical works within the road corridor, however would require significant road traffic management, hence RMS approval. The option requires significant physical works outside the road corridor and would require significant road traffic management. The construction timeline is anticipated to exceed 25 weeks. Key constraints include access, existing valuable habitat, traffic management and the need to dispose of excavated material.

Flood Impacts

Flood Impacts are minor positive. Flood immunity up to 4 EY (3-month ARI).

Environmental Impacts

Environmental impacts are anticipated to be significant. There would be a direct impact to 2.88 ha of native vegetation and a further 0.45 ha of non-native vegetation would be impacted. Environmental offset costs estimated to be $670,000 (excl. GST).

Estimated Capital Costs

The option is estimated to cost $4.1M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency), and the implementation would be subject to significant additional environmental assessment and approvals. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or a SIS, as well as a Biodiversity Management Plan.

Option B6	*Removal of overbank sediment (2m depth)*

Overview
The option is **considered unfeasible**. The creek is typically less than 1m below the overbank area, therefore the proposed 2m of floodplain excavation would result in significant lowering of the existing creek, resulting in an imbalance in the fluvial regime and a complete change to the morphology of the creek and floodplain. In addition, the entire vegetation and habitat would change and not be able to be readily rehabilitated.

Flood Impacts
Flood impacts would be significant-positive. Flood immunity up to 1 EY (1-year ARI).

Estimated Capital Costs
The option was not costed.

Option B7	*New levee, under road culverts.*

Overview
Option B7 is similar in nature to Option B3, less the requirement for floodplain sediment removal. The under-road culverts significantly increase the disturbance footprint, capital works and presents significant temporary road closure / partial closures. The option is considered to be constructible through open trench methods, whilst maintaining two-way traffic.

Environmental Impacts
The disturbance to sensitive and valuable habitat east of the road by culvert tail out channels is anticipated to cause significant environmental impacts. Indirect impacts to native vegetation and habitat of 0.22 ha (minimum) are estimated due to culvert works. There is an estimated environmental offset cost of $67k (excl. GST).

Flood Impacts
Flood impacts are significant positive. Flood immunity up to 1 EY (1-year ARI).

Estimated Capital Costs
The option is estimated to cost $8.1M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency), and the implementation would be subject to moderate additional environmental assessment, impacts and approvals.

The option does not address the ongoing issue of creek and floodplain sedimentation (existing sediment within the creek and floodplain moving downstream), and the resulting flood impacts.

Option O1	*Culvert capacity increase*

Overview
Under road culverts would require significant capital works and presents significant temporary partial road closures. The option is considered to be constructible through open trench methods, whilst maintaining two-way traffic. There would be the need for full or partial road closures during construction, however it is anticipated that such partial road closures could be undertaken whilst maintaining two lanes of flowing traffic (one each way), albeit at a reduced speed limit temporarily.

The key constraint would be the buried Optus cable which would require protecting or temporary realignment during construction.

Environmental Impacts
Given the proposed utilisation of an existing culvert alignment, it would be likely to result in significant impacts. Environmental offset cost is estimated at $12k (excl. GST).

Flood Impacts
Flood impacts are significant-positive. Flood immunity up to 1 EY (1-year ARI).

Estimated Capital Costs
The option is estimated to cost $1.2M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency).

Option O2	*Culvert capacity increase (additional to O1)*

Overview
The option would present similar considerations as Option O2, with only a slightly larger construction footprint due to the larger pipes.

Flood Impacts
Flood impacts are significant-positive. Flood immunity up to 0.5 EY (2-year ARI)

Environmental Impacts
Given the proposed utilisation of an existing culvert alignment, it would be likely to result in significant impacts. Environmental offset cost is estimated at $12k (excl. GST).

Estimated Capital Costs
The option is estimated to cost $1.6M (excl. GST) (total project cost, including project management, design, offsets, construction and contingency).

Option S1	*Bunds and localised low point drainage (i.e. flap-gated pipes)*

Overview
The option is considered to be feasible, with the primary consideration the approval from RMS for works within the road corridor. There would be a requirement for reduced travel speed limits during the anticipated 6-week construction period.

Flood Impacts
Flood impacts are significant-positive. Flood immunity up to 0.5 EY (2-year ARI).

Estimated Capital Costs
The option is estimated to cost $2.1M (exc. GST) (total project cost, including project management, design, offsets, construction and contingency).

If local drainage channels are required to offset local drainage impacts, an additional $126k (excl. GST) of environmental offsets may be required for 0.74ha of vegetation disturbance.

Based on the feasibility assessment, it is considered that all the proposed options, except for Option B6, are feasible to implement, subject to acceptance of environmental impacts and the perceived or actual cost/benefit. Due to the constraints posed, the estimated costs for most options are considerably higher than would be expected from a less constrained site.

Option B6 (2m sediment removal) is not considered feasible. The creek is typically less than 1m below the overbank (floodplain) area, therefore a 2m depth of floodplain excavation would result in a reduced creek profile, significant imbalance in the fluvial regime, as well as ponding. Such work would also make revegetation of the 'floodplain' unlikely.

Those options requiring physical works within the road corridor would require approval and possibly implementation by RMS. For such options, the primary consideration is available space for plant and equipment during construction, a need to limit road closures, in-ground services and traffic management / safety. Space constraints are a key consideration and impact significantly on the construction timeframe and cost.

Options requiring physical work outside the road corridor (i.e. floodplain sediment excavation, culvert tail out channels) present significant constructability constraints and particularly issues with environmental impacts. This is particularly relevant for options at The Bends, where direct disturbance of sensitive and valuable habitat would be likely.

It is understood that options outside the road corridor (i.e. floodplain sediment excavation) could be implemented by Council, with only approvals required from RMS (being required for temporary road closures / temporary changed traffic conditions). Other environmental approvals would be required.

Regarding staging, options outside the road corridor at The Bends (e.g. sediment excavation) can be implemented prior to other options within the road corridor and are not necessarily inter-dependant. Therefore, the sediment excavation option at the Bends could be implemented initially, with other options being implemented later.

Residual risks for option implementation include:

- The impact of localised pluvial flooding (ponding) remains a risk for options comprising levee construction or raising.
- further ongoing sediment infill and choking of the creek corridor could continue for options not including sediment removal. Further sedimentation could exacerbate the existing flooding issue.
- environmental approvals and the need for further assessment is required, primarily for sediment removal and road culvert options (at The Bends). Environmental impacts may not be considered acceptable.
- offset credit values are estimated at today's rates. It should be noted that these rates are changed every 3 months.
- RMS approvals regarding traffic management (for options outside the road corridor) or road closures and occupancy (for options within the road corridor) would be required. It is understood that limited consultation with RMS has taken place to date.
- the sediment contamination testing undertaken to inform this assessment was limited. To fully classify the sediment prior to removal would require significant additional testing. Should additional testing change the waste classification, then estimated disposal costs would increase significantly, and likely render the option unfeasible due to costs.

- the ability for the excavated sediment to be disposed of offsite (in the case of options involving sediment excavation) has been assumed.
- Several uncertainties remain regarding land ownership.
- Options have been tested based on present day conditions, including rainfall, site constraints and baseline environmental conditions. The present study has not taken account of climate change (potential increase in rainfall intensity) or sea level rise.
- A European Heritage Assessment has not been undertaken.

The feasibility assessment has identified several flood mitigation options, generally providing increasing flood immunity with increasing estimated costs. The best performing option(s) provide flood immunity up to 1 EY (1-year ARI) for the whole parkway. Such flood immunity is achieved with the combination of Option B3 (at The Bends) and Option O1 (at Oxford Falls), with estimated costs of $12.1M (excl. GST) and $1.2M (excl. GST), respectively ($13.3M in total).

Option B4 provides flood immunity up to 0.5 EY (2 year ARI) flood immunity at the Bends at an estimated cost of $13.8M (excl. GST), however the flood immunity of the whole parkway is not realised as it is limited by the Oxford Falls and Sports Academy sites.

Glossary of Terms

Annual Exceedance Probability (AEP)	The annual exceedance probability is a measure of the frequency of a rainfall event. It is the probability that a given rainfall total, accumulated in a given duration, will be exceeded in any one year. A one per cent AEP event is a rainfall event with a one per cent chance of being exceeded in magnitude in any year. The current Australian Rainfall and Runoff Guideline (Commonwealth of Australia, 2016) recommends the use of AEP terminology whereas historically, the term Average Recurrence Interval (ARI) was used. Where reference documents have used ARI, this has been converted to an equivalent AEP using the information below (Bureau of Meteorology, 2016).
Australian Height Datum (AHD)	A common reference level used in Australia which is similar to the height above sea level.
Average Recurrence Interval (ARI)	The average recurrence interval is a measure of the frequency of a rainfall event. It is the expected average value between exceedances of a given rainfall total accumulated over a given duration, e.g. 1 in 100 years. However, this sometimes resulted in the term being misinterpreted as implying the associated magnitude is only exceeded at regular intervals, and that it was referring to the elapsed time to the next exceedance. In fact, the time between events of a similar magnitude are random and unpredictable. For these reasons, the annual exceedance probability (AEP) is now the preferred terminology. The original flood studies referenced in this report were based used ARIs, and these have been converted to equivalent AEPs.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Design flood	A flood with a nominated probability or average recurrence interval.
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic meters per second or megalitres per day.
Flash flooding	Flooding occurring within about six hours of rain, usually the result of intense local rain and characterised by rapid rises in water-levels (BOM, 2016a).

Flood	For the purposes of this report, a flood is defined as the inundation of normally dry land or infrastructure by water which escapes from, is released from, is unable to enter, or overflows from the normal confines of a natural body of water or watercourse such as rivers, creeks or lakes, or any altered or modified body of water, including dams, canals, reservoirs and stormwater channels.
Flood-prone land	Land which is within the extent of the probable maximum flood and therefore prone to flooding. See probable maximum flood.
Floodplain	The area of land subject to inundation by floods up to and including the probable maximum flood.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Floodway	The area of the floodplain where a significant portion of flow is conveyed during floods. Usually aligned with naturally defined channels.
Geographical Information Systems (GIS)	A geographic information system (GIS) is a system designed to capture, store, manipulate, analyse, manage, and present all types of geographical data.
Probable maximum flood	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation (rainfall) and flood-producing catchment conditions that are reasonably possible at a given location.
Probability	The probability of an event (such as a flood) is the measure of the chance that the event will occur. It is a measure of the likelihood or unlikelihood of different outcomes.
Runoff	The amount of rainfall which ends up as streamflow, also known as rainfall excess.
Topography	Representation of the features and configuration of land surfaces.

1 Introduction

1.1 Purpose and Layout of this Report

Northern Beach Council (Council) engaged Royal HaskoningDHV (RHDHV) to undertake a flood mitigation options feasibility study to determine the appropriateness and effectiveness of measures to mitigate very frequent flooding of Wakehurst Parkway. Wakehurst Parkway is in the Northern Beaches Council LGA.

This report documents the review of available data, investigations and further data collection undertaken, the options feasibility assessment and presents a recommended approach to flood mitigation, for further assessment.

The study builds on the work undertaken by RHDHV in their 2018 Flood Mitigation Options Assessment Study (RHDHV, 2018).

The document is structured as follows:

- **Section 1 –** Introduction and Background (this section)
- **Section 2 –** Study Aims, Objectives and Scope
- **Section 3 –** Review of Available Data and Additional Studies
- **Section 4 –** Summary of Constraints
- **Section 5 –** Option Feasibility Assessment
- **Section 6 –** Residual Risks
- **Section 7 –** Conclusions and Recommendations

Further information is appended as follows:

- **Appendix A –** RHDHV Report (2018)
- **Appendix B –** Photo Record
- **Appendix C –** Existing Flood Mapping
- **Appendix D –** Heritage Assessment
- **Appendix E–** Ecological Constraints Report
- **Appendix F–** Sand Sheet Investigation Report
- **Appendix G –** Soil Contamination Report
- **Appendix H –** Services Search
- **Appendix I –** Flood Model Refinements
- **Appendix J –** Concept Design Plans
- **Appendix K** - Flood Impact Maps

1.2 Background

Wakehurst Parkway provides an important road connection in the Northern Beaches, linking Frenchs Forest with Narrabeen. Middle Creek runs alongside Wakehurst Parkway from Oxford Falls to Cromer, where it discharges to Narrabeen Lagoon.

Flooding from Middle Creek and its tributaries affects Wakehurst Parkway in this area, causing very frequent flooding. Very frequent flooding is defined in Australian Rainfall and Runoff (Geoscience Australia, 2016) as occurring more frequently than once a year. The very frequent flooding of the road causes the road to be regularly closed due to actual or anticipated flooding from Middle Creek during a range of rain events. The road is understood to be closed based on water level gauge readings and visual assessment. Due to the high volume of traffic present on the roadway, the impact of closure on the community is significant.

Ongoing and future requirements for flood mitigation is complicated by the local environment, a variety of constraints at the site and the involvement of a number of organisations and stakeholders.

The investigations undertaken by RHDHV (2018) confirmed the results of previous studies in 2013 (GHD for RMS) and 2017 (Cardno for Council), including that Wakehurst Parkway frequently floods (over road flooding) in three (3) key locations, namely:

1. The Sydney Academy of Sport and Recreation;
2. The Bends; and
3. Oxford Falls.

The location of the three (3) key flood-affected locations is shown below in **Figure 1**, along with the estimated extent of the 0.5 Exceedances per Year (EY) or 2 year Average Recurrence Interval (ARI) flood event.

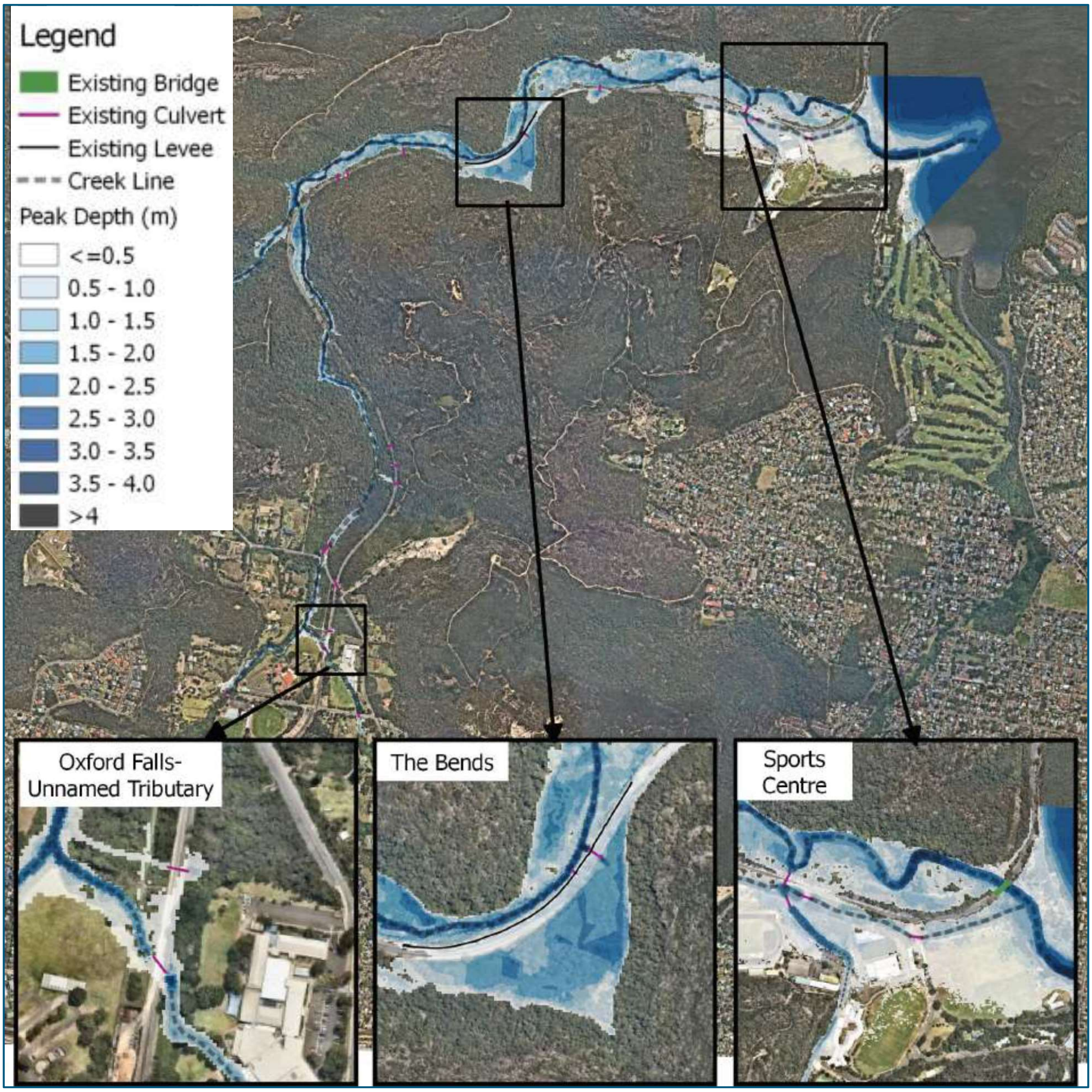

Figure 1: Modelled flood extent and depths in Middle Creek in the 0.5 EY (2 year ARI) flood event. The location of the three (3) key locations affected by over road flooding is shown by inserts (RHDHV, 2018).

The extent of flooding shown above in **Figure 1** defines the geographic extent of the study reported herein. Flood mapping for the existing situation, as a product of more current flood modelling by RHDHV, is presented in **Appendix C (Figure C1** to **C12)**.

1.3 Study Area

The general character of the study area is well described by Soil Conservation Service (2018) and repeated here (with minor additions) for context.

Middle Creek is located within the Narrabeen Lagoon Catchment and is a major tributary draining eastward toward Narrabeen Lagoon. The lower reaches of Middle Creek are brackish and subject to some tidal influence via Narrabeen Lagoon (when open to the sea).

NSW Department of Industry (DoI) Water classifies Middle Creek as a 3rd order stream with Snake Creek, Oxford Creek and Trefoil Creek feeding into this tributary. The upper reaches of the Middle Creek sub-catchment are dominated by the urban residential setting of Frenchs Forest and Oxford Falls with the study reach dominated by dense vegetation for the majority of its length.

The Middle Creek sub-catchment is approximately 10 km² in size and is prone to short duration 'flash flooding' due the steep surrounding topography. Middle Creek is defined by the valley margin which is made up of the Hawkesbury Sandstone formation (Geological Survey of NSW, 1983).

Below Oxford Falls, Middle Creek has a low gradient that flows along an alluvial floodplain. The channel is made up of intermittent benches and pool-riffle sequences with aquatic habitat attributes including large woody debris and overhanging vegetation. The banks and floodplain are densely vegetated with both native and exotic species with bank material dominated by course sand deposits. A delta formation is situated at the mouth of Middle Creek as it enters Narrabeen Lagoon.

The site is situated at approximately 10m AHD, with the top of the catchment located at approximately 150m AHD.

The riparian corridor is recognised as Key Fish Habitat by the Department of Primary Industries (DPI) Fisheries 2007.

1.4 Existing Flooding Problem

The existing flood problem has previously been documented in numerous reports, including most recently by Cardno (2017) and RHDHV (2018). Cardno (2017) reported that within the eight years of record analysed (2007 to 2014), the road was typically closed six to seven times per year as a result of flooding, with a median number of closure incidents of five per year.

The closing of the Parkway is understood to be initiated by mechanisms including the following:

- The water level gauge reading at The Bends (prior to 2017 a gauge further upstream was used),
- Reports by the public of over-road flooding; and
- NSW Police patrol observations.

CCTV monitoring of the roadway at Oxford Falls and visual inspections by NSW Police or RMS are then used to confirm flooding prior to closure of the road. A new CCTV camera is planned to be installed near the eastern gates, which are in the vicinity of the RMS heavy vehicle inspection station, west of Sydney Academy of Sport and Recreation. Following flooding, the road is re-opened following confirmation by NSW Police that flooding has subsided.

Flood modelling undertaken by RHDHV (2018) estimates that the roadway at the three key locations is inundated during the flood events as shown in **Table 1** below.

Table 1: Frequency of existing road inundation at the three (3) key locations, as estimated by flood modelling.

Case	Depth of road flooding from the Creek in the stated event (Excluding local effects from direct rainfall on road)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Academy of Sport	Not flooded	Not flooded	Not flooded	0.23m
The Bends	0.08m	0.35m	0.46m	0.88m
Oxford Falls	0.06m	0.09m	0.18m	0.21m

As can be seen from **Table 1**, The Bends is the most frequently inundated section of road along the Parkway and has therefore formed a primary focus of this study.

1.5 Previous Flood Mitigation Studies

Preliminary flood mitigation options were investigated by Cardno (2017). Options included sediment removal from Middle Creek, culvert upgrades, detention basins and the raising of Wakehurst Parkway. Results suggested that the removal of sediment from Middle Creek could provide minor reductions in flooding in the short term. The combination of vegetation removal with sediment removal showed greater flood benefits. However, no investigations of ongoing maintenance were undertaken.

The raising of Wakehurst Parkway in key locations and corresponding culvert upgrades appeared to provide a longer-term sustainable option to permanently reduce the incidence of flooding and road closures in larger flood events, however this would have a significant capital cost and would also likely have environmental impacts. The raising of Wakehurst Parkway is not under further investigation and was discounted as an option from this assessment.

The recent investigations for flood mitigation follow a previous history of investigations into rehabilitation and dredging of Middle Creek. Ecological rehabilitation (bush regeneration) has been undertaken, however no physical works on the creek have proceeded.

In 2018, RHDHV undertook a Flood Mitigation Options Assessment Study (RHDHV 2018) (refer **Appendix A**).

The following data collection and studies were undertaken in 2018 by Council to identify opportunities and constraints to potential flood mitigation, and informed the RHDHV (2018) study:

- Detailed creek / ground survey and bathymetric survey;
- Ecology and biodiversity study (GHD, 2018); and
- Sediment and geomorphic studies (Soil Conservation Service and Pietsch, 2018).

The aim of the RHDHV (2018) flood mitigation options assessment was to develop upon previous flood mitigation studies by refining and evaluating options and selecting a preferred option for mitigation of very frequent flood events on Wakehurst Parkway. Specifically, at the three key locations mentioned above.

The RHDHV (2018) study aimed to mitigate flooding on the road in events with a frequency of 2 to 4 exceedances per year (EY) on average. Specifically, the study objectives were to:

- Provide a detailed assessment of opportunities and constraints;
- Develop options (shortlist) in consideration of the opportunities and constraints;
- Provide a detailed assessment of each shortlisted options;
- Select and justify a preferred option; and
- Provide recommendations for further studies and data requirements, including briefing notes for selected further studies (Heritage and Contamination).

Following an options shortlisting process, nine (9) options were shortlisted for detailed assessment. These options comprised six (6) at The Bends, one (1) at the Academy of Sport, and two (2) at Oxford Falls Road. The shortlisted options and repeated below in **Table 2** for convenience.

Table 2: Options shortlisted for detailed assessment

Option	Description
The Bends	
Option B1	*New levee*
Option B2	*New levee and removal of 1m depth of overbank sediment*
Option B3	*New levee, removal of 1m depth of overbank sediment and under-road culverts*
Option B4	*New levee, removal of 1m depth of overbank sediment, under road culverts, and top up of existing levee.*
Option B5	*Removal of overbank sediment (1m depth)*
Option B6	*Removal of overbank sediment (2m depth)*
Option B7	*New levee, under road culverts.*
Oxford Falls Road	
Option O1	*Culvert capacity increase*
Option O2	*Culvert capacity increase (2 year ARI flood immunity)*
Sydney Academy of Sport and Recreation	
Option S1	*Bunds and localised low point drainage (i.e. flap-gated pipes)*

Through the findings of the RHDHV (2018) assessment, it was determined that the options be taken forward for further assessment by way of this feasibility study.

For the further assessment of the options, the following studies were considered to be required:

- Geotechnical investigation;
- Acid Sulfate Soils and Contamination Assessment;
- Aboriginal Heritage Assessment;
- Feasibility assessment (including preliminary costing and economic assessment, assessment of permissibility and risk assessment); and
- Services search, to locate (alignment and depth) of the sewer and gas mains.

2 Study Aims, Objectives and Scope

2.1 Study Aim

The aim of this study was to assess the feasibility or otherwise of the flood mitigation options previously developed by RHDHV (2018). The aim of flood mitigation options is to reduce the frequency of inundation without increasing the duration of inundation.

2.2 Scope and Objectives

2.2.1 Concept Design

The RHDHV (2018) derived preliminary options were progressed to preliminary concept designs, of sufficient for this assessment. The level of detail was suitable to identify physical constraints and assess feasibility in terms of constructability. Alternative concept designs were developed where considered necessary.

The preliminary concept design drawings (presented in Appendix J) accounted for:

- Safety;
- RMS requirements;
- Ausgrid requirements for the high voltage access track at Oxford Falls (west of northern pipe);
- Maintenance considerations;
- Long term sustainability, including renewed/new sediment deposits;
- Biodiversity (minimising extents);
- Soil conditions, including an investigation confirming of the sand sheet extent;
- Constructability and site considerations; and
- Any other considerations arising from the other aspects of the feasibility study e.g. permissibility, etc.

2.2.2 Planning and Approvals Assessment (Environmental Planning / Permissibility)

A planning and approvals assessment was undertaken to confirm the approval pathway, e.g. under SEPP infrastructure, and to confirm if an EIS or REF is required. Required permits were confirmed. In addition to planning and approvals, a preliminary environmental impact assessment was undertaken and the timing of works, including season variations and issues, was considered.

2.2.3 Constructability

Detail all relevant aspects of constructability, including but not limited to:

- Access;
- Methodology;
- Safety;
- Permitting and construction; and
- The degree of specialisation of the works and considerations regarding available resources and/or contractors.

2.2.4 Costing

A preliminary cost estimate was prepared for each option. High-level life cycle costings, considering long term aspects such as sedimentation, were provided qualitatively.

2.2.5 Risk Assessment

In addition to an assessment of feasibility, based on the aforementioned aspects, an assessment of residual of each option or option element was undertaken, including:

- Climate change and sea level rise;
- Stakeholder and community acceptance; and
- Consideration of the ‘do nothing’ option, including the potential for adverse impacts, e.g. on biodiversity, should works, e.g. sediment removal, not proceed; and
- Identification of key assumption or residual data gaps.

3 Data Review and Additional Studies

3.1 Previous Relevant Studies

Council provided a number of studies and investigations which have previously been carried out at and around the study area. A review of these studies was undertaken by RHDHV.

3.2 Data Received

A number of data were provided to RHDHV by Council (unless stated otherwise) at commencement or during the study. Data received and reviewed includes:

- Aboriginal Heritage Due Diligence assessment (Navin Officer Heritage Consultants, November 2018) (refer **Appendix D** for full report and below for summary);
- Aerial Photos (refer **Appendix B** for full selected photo record);
- Additional site inspections (refer **Appendix B** for full selected photo record);
- RMS Accident Report and Traffic counts (RMS, 2018) (refer below for summary);
- Land contamination report (SESL, December 2018) (refer **Appendix G** for full report and below for summary);
- Additional infill to the Topographic Survey; and
- Sand sheet extent investigation (Soil Conservation Services, 2018) (refer **Appendix F** for full report and below for summary).

The above, along with additional studies undertaken are summarised below in **Section 3.3**.

3.3 Summary of Additional Studies

3.3.1 RMS Traffic and Accident Counts

Accident Counts

A Summary Crash Report compiled by NSW Roads and Maritime Service (RMS) was provided for information. The Summary Crash Report comprises reported crashes along Wakehurst Parkway, between Dreadnought Road and Sydney Academy of Sport. The data was recorded between the 1st of January 2013 to the 31st of December 2017.

Crash/collision types: There were 29 crashes overall. The majority of crashes were car crashes (93.1%) followed by 10.3% involving a light truck crash. 62.1% of these crashes involved multiple vehicles while 37.9% involves single vehicles. 24.1% of these crashes were head on, primarily resulting from one car driving on the incorrect side of the road, 20.7% of the crashes resulted from the car losing control on the curve and hitting an object off road, 13.8% were rear end crashes, and 10.3% resulted from a vehicle leaving a driveway.

Contributing factors: Speeding was a large contributing factor involved in 51.7% of crashes and school travel time was involved in 27.6% of the collisions. 48.3% of these crashes occurred when the road surface condition was wet. The majority of these accidents (75.9%) occurred in the daylight while 17.2% occurred in darkness. The crashes all occurred whilst the speed limit was 80km/hr.

Injuries: There have been 32 casualties in total with 40.6% being moderately injured, 37.5% seriously injured and 21.9% with minor injuries. 31% of all crashes resulted in no causalities.

Occurrence: A large number (9) of these 29 accidents occurred in 2013 resulting in 10 casualties, whilst the safest year was 2014 with 3 crashes and 1 casualty. The rest of the collisions were spread fairly evenly over 2015-2017 with a peak in casualties occurring in 2017 (9). These collisions were most probable on Wednesday **–** Saturday with 2 occurring on Labour Day and 3 during the December and January holiday period.

Location: 93.1% of these crashes did not occur at an intersection and did not occur on a freeway, state highway or unclassified road.

Traffic Counts: Wakehurst Parkway typically experiences 8,000 trips in either direction per day (NSW Roads and Maritime Service, 2012), with some minor variation between weekdays and weekends. There is not current (up-to-date) traffic counts for Wakehurst Parkway, however, the RMS website (https://www.rms.nsw.gov.au/about/corporate-publications/statistics/traffic-volumes/aadt-map/index.html#/?z=15&lat=-33.73524848996451&lon=151.25303317582677), indicates that Pittwater Road north and south of Wakehurst Parkway, suggests ~20k per day in both directions (i.e. 40k).

Although specific and reliable data is lacking, it as a reasonable conclusion to characterise the road an extremely busy with a consistent flow of high speed (80kph) traffic for the majority of the day.

3.3.2 Sediment Characterisation and Sand Sheet Extent

In late 2018 and early 2019 Soil Conservation Services undertook an investigation into the extent and character of the existing sand sheet forming the in-creek and overbank sediment. Refer **Appendix F** for full findings. Specifically, the investigation aimed to determine the nature of the overbank (floodplain material) and establish to what extent the material comprised clean sand. The Soil Conservation Services investigation determined that the existing overbank material typically comprised sand with interbedded silts and clays. In the upper portion of the sand sheet, at The Bends, there was clean sand.

In addition, as part of the Acid Sulfate Soil (ASS) and Contamination Investigation (see Section 3.3.3 below and **Appendix G)**, SESL (2018) conducted a limited sediment characterisation at the proposed potential works areas (refer **Figure 2** and **Figure 3**). Selected results are presented in **Table 3** and **Table 4** below. The SESL (2018) result correlate with the Soil Conservation Services investigation.

A number of images taken during the SESL (2018) investigation and by RHDHV during various site investigations are presented below in **Figure 4** to **Figure 7**.

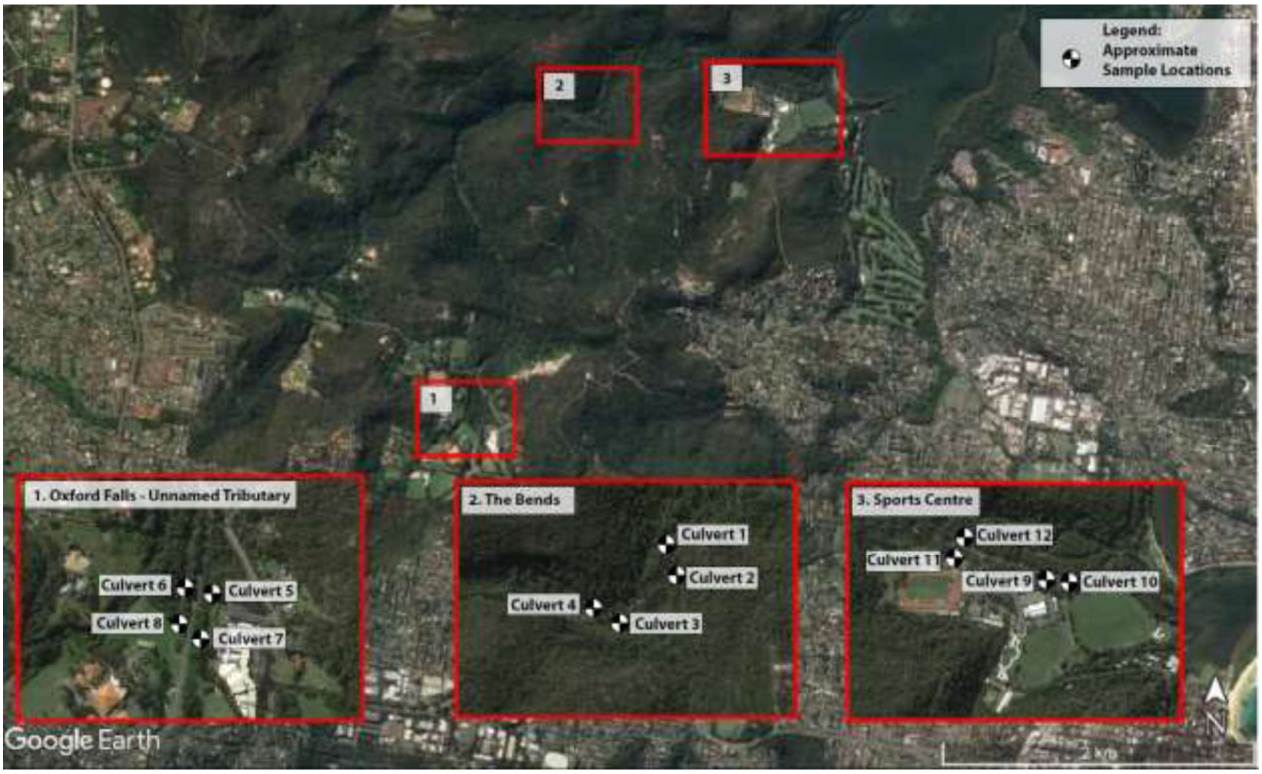

Figure 2: Sampling locations at proposed culvert sites (SESL, 2018)

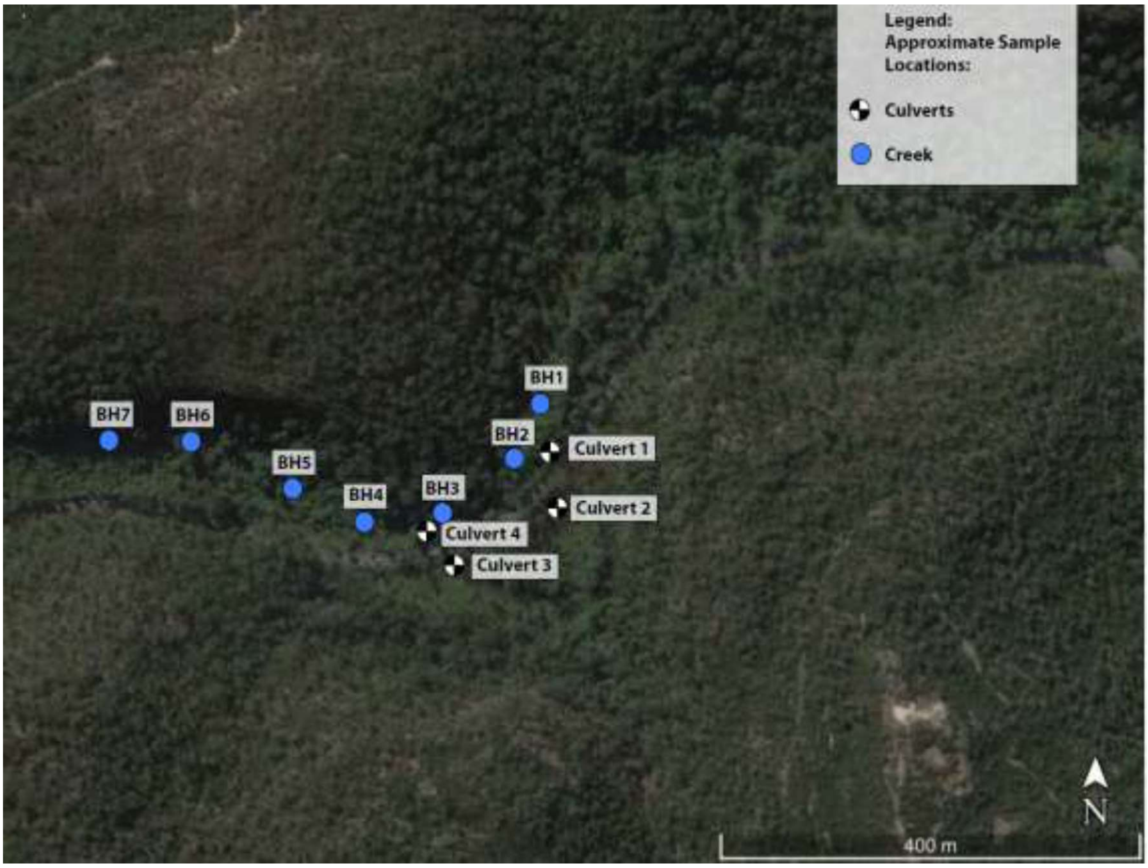

Figure 3: Sampling locations within the creek (SESL, 2018)

Table 3: Results of sediment characterisation investigation at proposed culvert locations (SESL, 2018)

Sample Name	Sample Depth approx. (mm)	Sample Location Description
Culvert 1	800	Northern side of Wakehurst Parkway, within vegetation approximately 5-10 m from the road. 0-400: Brown sandy loam (topsoil) with organics 400-800: Brown sandy clay
Culvert 2	500	Southern side of Wakehurst Parkway, within bog-like area, approximately 5-10 m from the road. 0-500: Brown sandy clay (high moisture content)
Culvert 3	500	Southern side of Wakehurst Parkway, within bog-like area, approximately 5-10 m from the road. 0-500: Brown sandy clay
Culvert 4	500	Northern side of Wakehurst Parkway, within vegetation approximately 5-10 m from the road. 0-400: Brown loamy fill, with general rubbish and building wastes 400-500: Brown clayey sand
Culvert 5	500	Eastern side of Wakehurst Parkway, approximately 5 m from the road. 0-300: Road base/fill 300-500: Clayey sand/sandy clay
Culvert 6	500	Western side of Wakehurst Parkway, approximately 5 m from the road. 0-300: Road base/fill 300-500: Clayey sand/sandy clay
Culvert 7 – above Retaining Wall	500	Eastern side of Wakehurst Parkway, approximately 5 m from the road. Sample collected from above the retaining wall. Brown sandy clay
Culvert 8 – Midbank	500	Western side of Wakehurst Parkway, approximately 5 m from the road. Sample taken from halfway down the creek bank. Brown clayey sand
Culvert 9	500	Collected from the midbank adjacent to the existing culvert (western side). 0-300: Dark brown organic matter 300-500: Highly organic grey sandy clay
Culvert 10	500	Collected from the mid-bank adjacent to the existing culvert (eastern side). 0-300: Dark brown organic matter 300-500: Highly organic grey sandy clay
Culvert 11	300-700	Southern side of Wakehurst Parkway, halfway down embankment 5-10m from the road 0-400: Brown highly organic loam 400-700: Organic sandy clay/clayey sand
Culvert 12	300-700	Northern side of Wakehurst Parkway, halfway down embankment 5-10m from the road 0-400: Brown highly organic loam 400-700: Organic sandy clay/clayey sand

Table 4: Results of sediment characterisation investigation in floodplain (SESL, 2018)

Sample Name	Sample Depth approx. (mm)	Soil Profile Description
BH1	0-200 500-600 800-900	0-700: White/yellow coarse sand 700-800: Dark brown sandy loam
BH2	0-200 500-600 1100-1200	0-200: Coarse sand with significant organics 200-800: Coarse sand 800-1200: Loamy sand
BH3	0-200 200-300 800-900	0-250: Coarse sand 250-300: Brown sandy loam 300-1000: Coarse sand
BH4	0-200 300-400 500-700	0-500: Coarse sand 500-800: Dark brown sandy clay loam
BH5	0-200 500-600 700-800	0-700: Coarse sand with minor loam inclusions 700-800: Dark brown sandy clay loam, plastic inclusions
BH6	0-200 300-400 550-700	0-550: Coarse sand with minor loam inclusions 550-700: Dark brown sandy clay loam
BH7	0-200 400-600 800-1000	0-600: Coarse sand with minor loam inclusions 600-1000: Dark brown sandy clay loam

Figure 4: Profile of the material augured at BH1 (SESL, 2018). Phot taken 31/10/2018.

Figure 5: Profile of the material at BH5 (SESL, 2018). Photo taken 31/10/2018.

Figure 6: (a) and (b) upper horizon. approximate location of BH1 on LHB (looking downstream) floodplain 21/11/18

Figure 7: In-creek sand at approximate location of the SESL (2018) BH7. Photo taken looking downstream.

3.3.3 Acid Sulfate Soil (ASS) and Contamination Investigation

SESL (2018) conducted an Acid Sulfate Soil (ASS) and Contamination Investigation at the site of expected soil disturbance. This investigation included the assessment of soils within the vicinity of six (6) proposed culvert upgrades and creek sediment removal, adjacent to Wakehurst Parkway (refer **Figure 2** and **Figure 3** above).

The environmental assessment works undertaken during this ASS investigation comprised of the following:

- Visual inspection of the locations of proposed site works on 3/10/2018, 26/10/2018 and 31/10/2018;
- Collection and analysis of 19 soil samples for sPOCAS analysis;
- Collection and analysis of 22 soil samples for acid sulfate screens;
- Collection and analysis of 33 soil samples for contamination analysis;
- Preparation of this report detailing methodologies used during this investigation, results, management strategies and conclusions regarding the acid sulfate soil risk associated with the proposed development at the site.

Investigative work was conducted in accordance with the following applicable guidelines:

- Acid Sulfate Soils Manual (NSW Acid Sulfate Soils Management Advisory Committee, 1998); and
- Assessing and Managing Acid Sulfate Soils - Guidelines for and Management in NSW Coastal Areas (EPA, 1995).
- NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014);

The report was based on the field data obtained from samples collected from the proposed inlet and outlet locations of six (6) culverts in the investigation area and material collected from the subject sediments at Middle Creek (the Bends).

Based on the findings of the assessment, the soils within the proximity of some of the proposed culvert locations are considered to be potential and actual acid sulfate soil. SESL recommends that the proposed excavation works must be managed under the site-specific Acid Sulfate Soil Management Plan (ASSMP).

Based on limited assessment and in accordance with the NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014), the soils proposed for excavation within the proximity of the culverts meet the criteria for General Solid Waste. In accordance with landfill’s Environmental Protection Licenses (EPL), the material is not considered suitable for recycling due to elevated benzo(a)pyrene, nickel and lead.

Soils proposed for excavation within the subject area of Middle Creek (The Bends) are considered to not be Acid Sulfate Soils, and do not require management under an ASSMP. SESL suggests that the observed acidity is likely the result of extensive organic matter within the subject materials, and not the result of present sulfur.

In accordance with the NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014), all samples collected from within creek sediments meet the criteria for General Solid Waste. However, based on the results of this limited assessment, SESL recommends that the subject soils proposed for excavation will meet the requirements for classification as Excavated Natural Material (ENM), and that consideration should be given to further assessment for the classification of these soils as ENM, to reduce the cost of offsite disposal.

3.3.4 Aboriginal Heritage Due Diligence Assessment

An Aboriginal Heritage Due Diligence assessment was undertaken by Navin Officer Heritage Consultants (November 2018).

58 Aboriginal site recordings and an Aboriginal place are listed on the OEH AHIMS for the area around the Wakehurst Parkway study area. None are located within the current study area.

Two locally listed historic sites sit in close proximity to the study area. Middle Creek Bridge No. 2 (I151) sits 10 metres away from the sediment removal area at The Bends, and Bridge No. 3 over Middle Creek (I146) sits 25 metres away from the proposed channel at the Sports Academy. There are no plans for the heritage sites to be impacted by the proposal.

Background research and field inspection of the study area did not identify any Aboriginal sites or potential archaeological deposits (PADs) in the study area. The area has been disturbed since European exploration of the area. The construction of Wakehurst Parkway and sediment build-up have had a massive impact on the area in particular.

It is recommended that:

1. No further archaeological assessment is required for the Wakehurst Parkway Flood Mitigation project.
2. The unanticipated discovery protocols included in Appendix 2 should be put in place for the project.
3. A copy of this report should be provided to the Metro Local Aboriginal Land Council.

3.3.5 Services and Utility Location

A Dial Before You Dig (DBYD) search was undertaken by RHDHV in June 2018 (Job:14213377 SEQ:71440601 - Wakehurst Parkway Allambie Heights NSW 2100). Results of the DBYD searches provide a useful overview of the services within the area and are summarised below. In addition, Council commissioned Land Surveys and Utility Mapping to undertake services locating at the three key areas. The results of the services locating are presented in **Appendix H**.

The Bends and Sydney Academy of Sport and Recreation

Two services / utilities were identified within the potential works area(s), namely:

- Gas (Jemena); and
- Sewer (Sydney Water Corporation).

The gas main is shown on the DBYD plans to be a 15 inch cast iron pressurised gas main (‘Secondary Main’) at 1050 kPa. The alignment of the gas main appears to generally follow the alignment of the road and to be contained within the road reserve, western road shoulder (refer **Figure 8** and **Figure 9**). The Land Surveys and Utility Mapping plans indicate that the depth to the gas pipe at The Bends is typically 750mm.

At the Academy of Sport, the gas main crosses the creek, either within the road bridge superstructure or under the creek. The depth of the gas main is indicated on the Land Surveys and Utility Mapping plans to be between 1.8m and 1.25 m below the road surface.

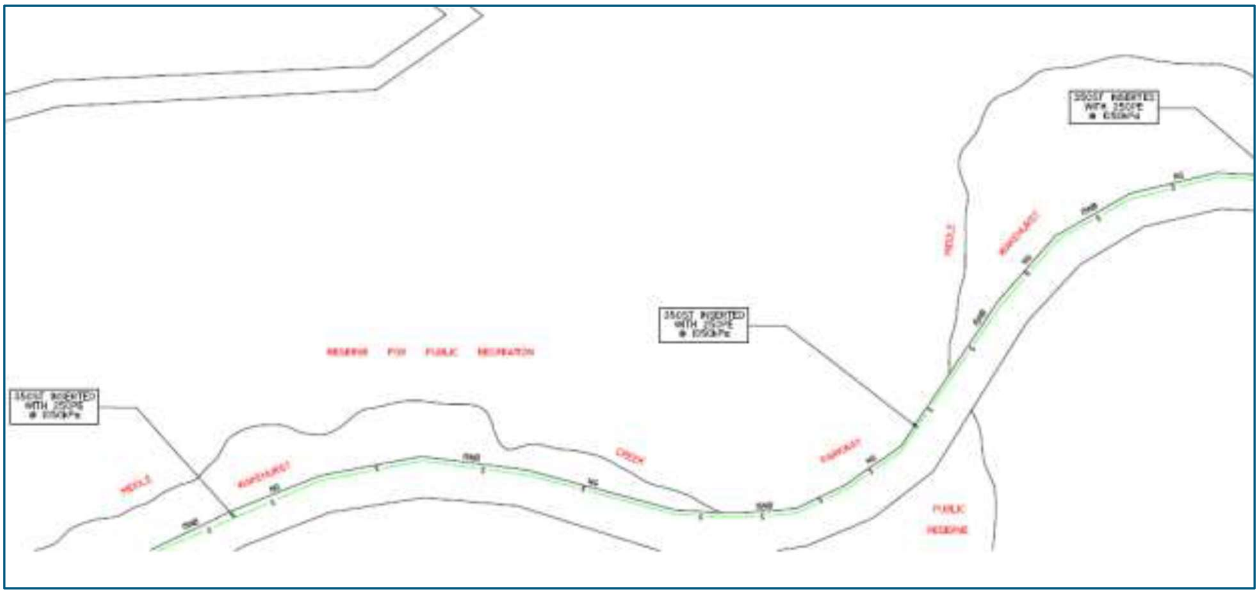

Figure 8: Gas main at The Bends.

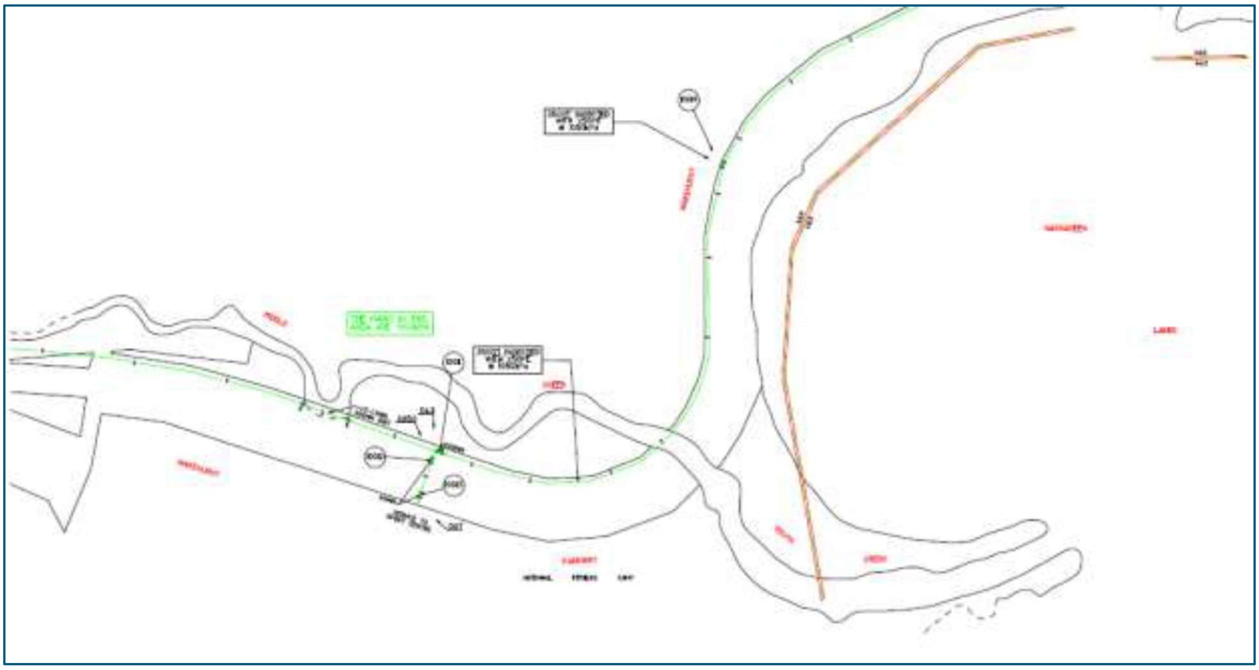

Figure 9: Gas main at the Sydney Academy of Sport and Recreation.

At The Bends and the Academy of Sport areas, the sewer main is shown on the DBYD plans to be a 375 mm diameter Ductile Iron Cement (mortar) Lined pipe. The sewer appears to run down the centreline of the road, before heading north away from the road alignment after The Bends (refer **Figure 10**). As the sewer heads north away from the road, it crosses the creek.

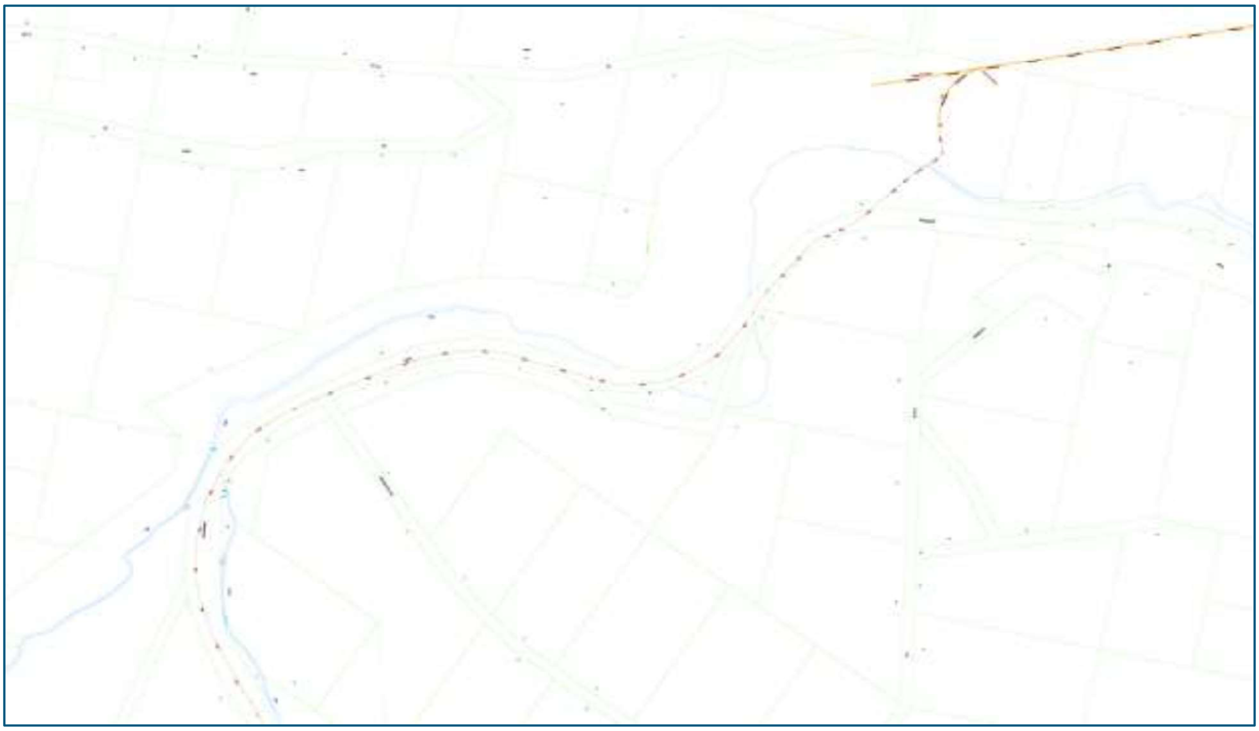

Figure 10: Sewer main at The Bends and Sydney Academy of Sport and Recreation.

According to the Land Surveys and Utility Mapping, the depth of the sewer at The Bends ranges between 500mm and 700mm below the road surface (refer **Appendix H**). The service is likely a gravity main running south to north until the access track.

From the Sydney Water Access Track, the main passes through the hill cut in rock. From there it crosses Deep Creek above ground (visible on aerial photo) goes through Elanora Heights to the Warriewood sewerage treatment plant, via at least one pumping station (Northern Beaches Council pers. Comms).

Oxford Falls

At Oxford Falls, a sewer main is shown on the DBYD plans to be a 375 mm diameter Vitrified Clay pipe running parallel to Middle Creek (refer **Figure 11**). The pipe is buried typically to a depth greater than 3m. The sewer pipe is not located in the road footprint, therefore is not expected to conflict with potential flood mitigation options (e.g. road culvert augmentation).

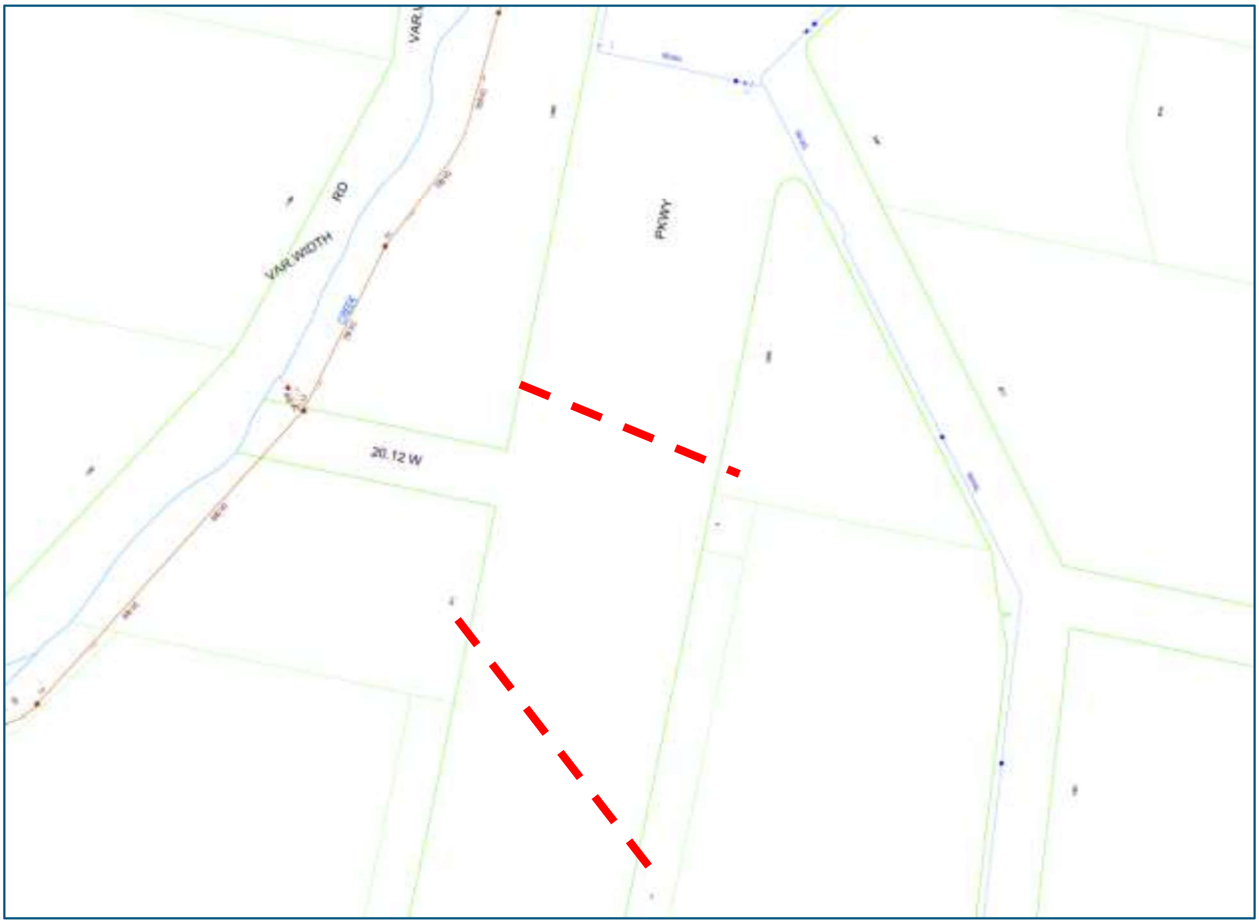

Figure 11: Sydney Water Corporation sewer main adjacent to Middle Creek. The approximate location of existing culverts is shown by red dashed lines.

There are Telstra services contained within the road corridor south of the southern set of culverts at Oxford Falls. These do not appear to cross the existing culverts. In addition, there is an Optus underground optic fibre cable (a major optic fibre telecommunications asset) within the Wakehurst Parkway road corridor, running generally parallel with the road alignment. These services have not been located by the Land Surveys and Utility Mapping services search.

A gas main is shown on the DBYD plans to be a 250mm polyethylene pressurised gas main (‘Secondary Main’) at 1050kPA. The alignment of the gas main appears to generally follow the alignment of the road and appears to be contained within the road reserve (centreline) (refer **Figure 12**).

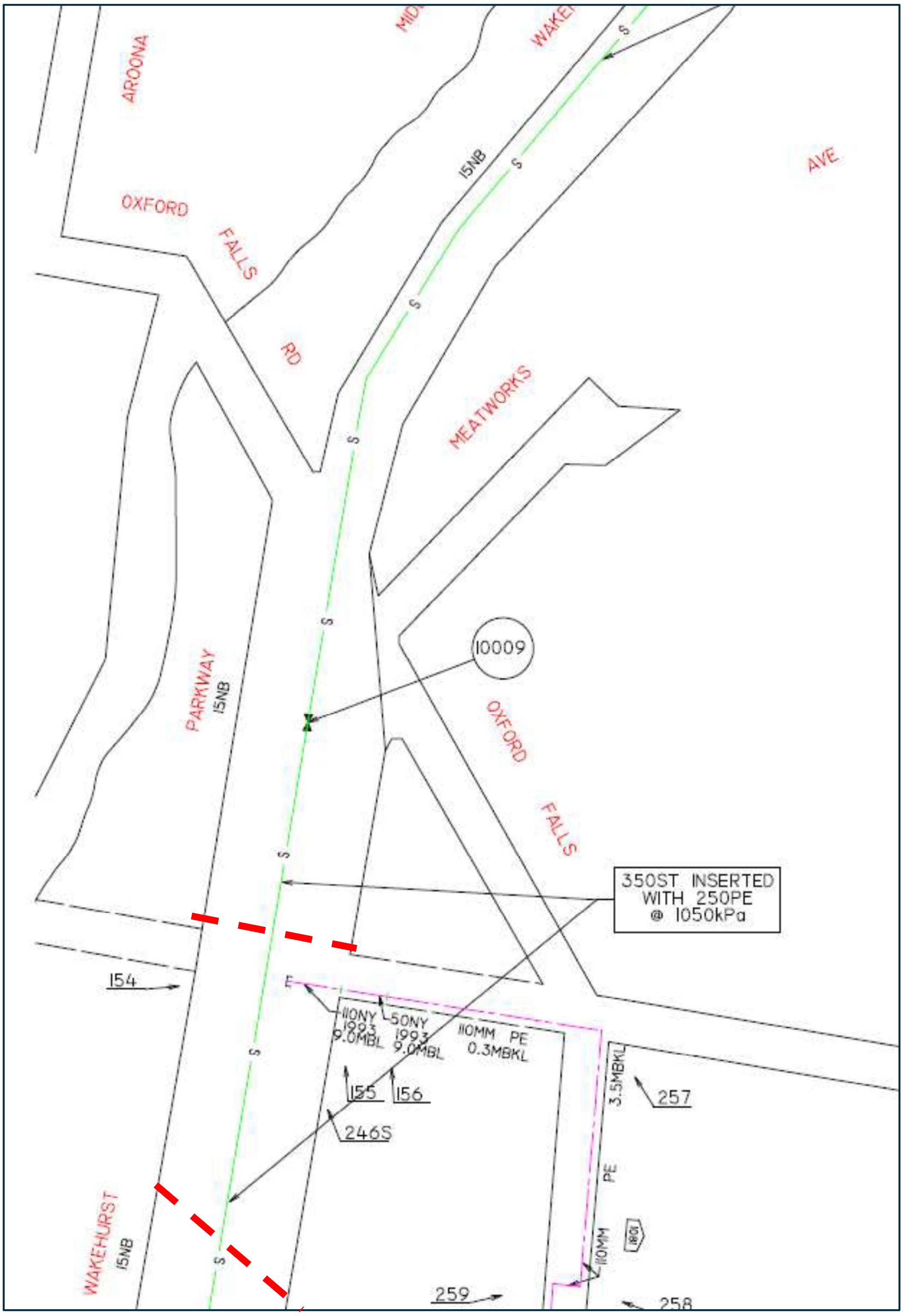

Figure 12: Gas main at Oxford Falls. The approximate locations of the two existing culvert road crossings are shown by dashed red lines.

3.3.6 Flood Modelling

Following refinement of the concept designs, the flood hydraulic model was updated by RHDHV and re-run. Refinements made to the model are detailed in **Appendix I**, whilst the mapped results of flood modelling are presented in **Appendix K**.

3.3.7 Constructability Workshop

A constructability workshop was held between Council and RHDHV on the 16th November 2018. The workshop included input from various Council officers, as well as external specialists. Attendees are listed below in **Table 5**.

Table 5: Constructability workshop attendees.

Name	Position	Organisation
Fiona Coe Adrian Turnbull Brendan Smith Andrew Camarsh (Michael England) Phil	Engineering Project Manager Manager Coasts and Catchments Team Leader Biodiversity & Planning Manager Major Infrastructure Projects (Manager Major Building Projects)	Northern Beaches Council
Nick Lewis Ben Patterson	Senior Scientist, Rivers & Coasts Associate Director – Rivers & Water Management	Haskoning Australia
Stephen Mitchell	Pre-Contracts Manager	Waterway Constructions
Dan Owens	Senior Project Manager	Soil Conservation Service

Key findings of the constructability workshop were as follow:

Under road culverts

- Under boring ruled out due to space requirements.
- Open trenching for culvert installation preferred.
- Two lanes required at all times. No full or partial road closures would be acceptable. Minimum lanes width should be provided.
- Require widening the road temporarily.
- Provision should be made for access to new culvert aprons for maintenance and inspection.

Sand extraction

- Pumping ruled out due to distance.

Reducing environmental impacts

- Key habitat to east of road at bends.
- Key habitat to west of creek at bends.

4 Summary of Constraints

4.1 Ecology

Constraints Summary

The GHD (2018) report highlighted a number of key constraints relating to ecology within the study area which may limit proposals for flood mitigation works. These include:

- Impacts on Coastal Wetlands – should be avoided or minimised as far as possible. Potential for impacts may trigger the requirement for an EIS, potentially increasing assessment and offset requirements
- Impacts on Endangered Ecological Communities – should be avoided as far as possible or minimised. Assessments of significance in accordance with section 7.3 of the BC Act and the EPBC Act significant impact guidelines would be required where threatened biota or their habitat would be affected.
- Impacts on twelve (12) identified threatened faunal species (feeding, breeding and roosting sites) should be avoided as far as possible or minimised. Assessments of significance in accordance with section 7.3 of the BC Act and the EPBC Act significant impact guidelines would be required where threatened biota or their habitat would be affected.
- Impacts on native trees – should be avoided as far as possible.

Further detail on these constraints is set out in the sections below and described further in the report.

Habitat Constraints

Proposed works have the potential to affect four (4) habitats identified as endangered ecological communities (EECs) under the Biodiversity Conservation Act 2017. These are:

- Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South-east Corner Bioregions.
- Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South-east Corner Bioregions.
- Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions.
- Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions.

The majority of vegetation along Middle Creek comprises of EEC habitat with Swamp Sclerophyll Forest comprising the majority of the vegetation. A significant impact on this habitat is possible depending on the location and extent of the works. There is potential for impacts on other EEC habitats depending on the location and extent of the proposed works.

Impacts of works on habitats close to the road edges at The Bends may be lower as habitat here tends to be of a poorer quality due to high occurrence of weed species.

Species Constraints

Ecological survey work was undertaken in 2018 to build on existing data from a number of historic surveys (including a 2015 study of the Narrabeen Lagoon catchment and surveys from a Species Impact Statement for the Narrabeen Lagoon multi-use trail (2007 & 2009).

The proposed works have the potential to impact on twelve (12) faunal species identified as threatened under the Biodiversity Conservation Act 2017. These are:

- Black Bittern – foraging and potential breeding habitat
- Eastern Osprey – breeding habitat and known nest site (restrictions on works timings in location of nest sites)
- Glossy Black Cockatoo – breeding and foraging habitat
- Powerful Owl – breeding habitat and known nest site (restrictions on works timings in location of nest site)
- Sooty Owl – breeding and foraging habitat
- Southern Myotis – breeding, foraging and roosting habitat
- Eastern Freetail Bat – foraging and breeding habitat
- Eastern Bentwing bat – foraging habitat
- Grey Headed Flying Fox – foraging habitat
- Red Crowned Toadlet
- Little Bentwing Bat – foraging habitat
- Large Eared Pied Bat – foraging habitat
- Greater Broad Nosed Bat – foraging and potential breeding habitat

For most of the species identified, potential impacts would be from removal of small areas of foraging habitat or disturbance of roosting sites. Significant effects on species are unlikely to occur from these impacts. Known nest locations for Eastern Osprey should not be removed and there is potential for noise disturbance impacts during the nesting season. There is potential for significant effects on Black Bittern from clearance of breeding habitat.

Whilst no threatened species of fish have been recorded there are constraints relating to potential fish habitat within Middle Creek. The riparian corridor is recognised as Key Fish Habitat by the Department of Primary Industries (DPI) Fisheries 2007. For works within the watercourse, Permit would-be required from NSW DPI Fishieries under Parts 2 & 7 of the Fisheries Management Act 1994.

Depending upon the level of in-stream disturbance required during modification works, removal or alteration of the quantity and quality of the woody debris within the creek channel may occur. In-stream woody debris provides important habitat structure for aquatic fauna and alterations to this habitat may potentially impact upon the fish communities within Middle Creek.

No threatened species of flora were recorded during the survey, and there are no previous records in the study area, however consideration should be given to the possible occurrence of the following plant species in areas of specific habitat:

- Along the creekline:
  Callistemon linearifolius, Deyeuxia appressa, Grevillea shiressii, Triplarina imbricata, Haloragodendron lucasii, Leptospermum deanei, Melaleuca biconvexa and Persoonia mollis subsp. maxima are species that have been recorded close to creeklines and within 10 km of the study area.

  Terrestrial orchid species including Caladenia tessellata, Diuris bracteata and Cryptostylis hunteriana have been recorded within 10 km in similar habitat to that within Bangalay-Smooth Barked Apple forest in the study area. No individuals of these species would have been detectable at the time of the survey.

- Escarpment slopes:
  Asterolasia elegans, *Acacia bynoena*, *Cynanchum elegans* and *Acacia terminalis subsp. terminalis* are threatened species that have been recorded within 10 km of the study area. The most likely habitats for these species are located on the escarpment slopes within the study area, and therefore unlikely to be affected by the proposed works.

4.2 Geomorphology

The geomorphology and sediment regime of Middle Creek is a highly dynamic environment, and one which has changed rapidly over the past 80 years (Pietsch and Soil Conservation Service, 2018).

The creek is a sediment transport and deposition zone.

Within the central reaches of the creek (immediately upstream and downstream of The Bends), significant over bank sedimentation has occurred. Ongoing accelerated aggradation on the floodplain derived from diffuse surface erosion upstream has occurred over an area of approximately 83,000 m^2 in the vicinity of the junction of Middle Creek and Oxford Creek, since approximately AD 1940. The scale of the deposit (~166,000 m3) occupies a significantly large proportion of the floodplain cross section that it is considered to be a contributor to elevated flood heights recorded at key locations on Wakehurst Parkway affected by frequent flooding.

Pietsch and Soil Conservation Service (2018) were of the opinion that dredging of the channel is not recommended, as it could cause upstream instability and remobilisation of the store of sediment on the floodplain. It may also cause a proportion of the sediment discharge currently being directed to the floodplain sink, to be retained within the channel and transported downstream. As the annual aggradation of the floodplain is estimated to be 2075 m^3, the danger the dredged channel could simply infill if some or all of this was retained within the channel, is high.

4.3 Heritage

As determined by the Aboriginal Heritage Due Diligence assessment (Navin Officer Heritage Consultants, November 2018), no Aboriginal site recordings or Aboriginal places are located within the current study area. In addition, no heritage sites are anticipated to be impacted by the proposal. Background research and field inspection of the study area did not identify any Aboriginal sites or potential archaeological deposits (PADs) in the study area.

The area has been disturbed since European exploration of the area. The construction of Wakehurst Parkway and sediment build-up have had a massive impact on the area in particular.

(Navin Officer Heritage Consultants, November (2018) considered that no further archaeological assessment is required for the Wakehurst Parkway Flood Mitigation project, however the Unanticipated Discovery Protocols should be put in place for the project.

4.4 Traffic and Access

Wakehurst Parkway typically experiences 8,000 trips in either direction per day (NSW Roads and Maritime Service, 2012), with some minor variation between weekdays and weekends.

The site between Oxford Falls Road and Narrabeen is accessible only by Wakehurst Parkway. Access to the subject site is restricted by the limited pullover capacity of Wakehurst Parkway (refer **Figure 13**,

Figure 14 and **Figure 15**). In addition, access to the channel is restricted by the dense vegetation of the floodplain and riparian zone.

A Sydney Water access track exists within the lower reaches of the Study Area and forms the only access track to the channel of Middle Creek. Access to the channel and floodplain, would be a key contributing factor to any flood mitigation works at Middle Creek.

Figure 13: Wakehurst Parkway looking northbound from upstream of The Bends (Source Google Street View).

Figure 14: Wakehurst Parkway looking northbound at The Bends (Photo taken on 10th May by RHDHV personnel).

Figure 15: Wakehurst Parkway looking southbound at The Bends (Photo taken on 10th May by RHDHV personnel).

4.5 Land Contamination

Land contamination presents a major consideration.

Based on the findings of this assessment undertaken by SESL, the soils within the proximity of some of the proposed culvert locations are considered to be potential and actual acid sulfate soil. SESL recommends that the proposed excavation works must be managed under the site-specific Acid Sulfate Soil Management Plan (ASSMP).

Based on limited assessment and in accordance with the NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014), the soils proposed for excavation within the proximity of the culverts meet the criteria for General Solid Waste. In accordance with landfill's Environmental Protection Licenses (EPL), the material is not considered suitable for recycling due to elevated benzo(a)pyrene, nickel and lead.

Soils proposed for excavation within the subject area of Middle Creek (The Bends) are considered to not be Acid Sulfate Soils, and do not require management under an ASSMP. SESL suggests that the observed acidity is likely the result of extensive organic matter within the subject materials, and not the result of present sulfur.

In accordance with the NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014), all samples collected from within creek sediments meet the criteria for General Solid Waste. However, based on the results of this limited assessment, SESL recommends that the subject soils proposed for excavation will meet the requirements for classification as Excavated Natural Material (ENM), and that consideration should be given to further assessment for the classification of these soils as ENM, to reduce the cost of offsite disposal.

4.6 Land Ownership

Selected land tenure maps were provided to RHDHV by Council. The maps are presented in RHDHV (2018). The maps demonstrate that for the majority of the potential works area, including the creek and immediate creek banks and floodplain are under either Crown or Council ownership. The road corridor is understood to be under RMS ownership.

Parts of the potential works area at The Bends, including portions of the floodplain to the south of Wakehurst Parkway and the left hand bank (looking downstream) of the main channel, are under ownership of the Metropolitan Local Aboriginal Land Council.

5 Option Feasibility Assessment

5.1 Preamble

Following the options shortlisting process, documented in the above section (Section 5), nine (9) options were shortlisted for detailed assessment.

The options comprised seven (7) at The Bends, one (1) at the Sydney Academy of Sport and Recreation, and two (2) at Oxford Falls Road. The shortlisted options are presented below in **Table 6**, along with an ID (Option B1, 2 ….etc.) and a brief description.

Table 6: Options shortlisted for detailed assessment

Option ID	Description
The Bends	
Option B1	*New levee*
Option B2	*New levee and removal of 1m depth of overbank sediment*
Option B3	*New levee, removal of 1m depth of overbank sediment and under-road culverts*
Option B4	*New levee, removal of 1m depth of overbank sediment, under road culverts, and top up of existing levee.*
Option B5	*Removal of overbank sediment (1m depth)*
Option B6	*Removal of overbank sediment (2m depth)*
Option B7	*New levee and under road culverts.*
Oxford Falls Road	
Option O1	*Culvert capacity increase*
Option O2	*Culvert capacity increase (2 year ARI flood immunity)*
Sydney Academy of Sport and Recreation	
Option S1	*Bunds and localised low point drainage (i.e. flap-gated pipes)*

5.2 Option B1

5.2.1 Option Description & Intended Hydraulic Performance

Option B1 comprises construction of a **new levee** on the south eastern side of the road at The Bends.

The aim of this option is to relieve flooding of the roadway at The Bends by containing flood water (up to a certain depth/elevation) to the floodplain on the east of the road and restrict overtopping of the road from the south side of the road. Flood water currently passes under the road culverts from the creek (west to east), enters the south eastern floodplain (where it is added to by a southern tributary) and rises above the road level. The maximum new levee height would be as per the existing levee on the western side of the road at The Bends, which is approximately 1m above road level.

5.2.2 Concept Design

Due to space constraints, the levee is considered to be best constructed using a bund wall to limit the footprint and contain the works to within the road corridor. There is not considered sufficient space for a more conventional earth embankment. A design has been developed to RMS standards using a concrete barrier. For concept design sketches of Option B1 please refer to **Appendix J.**

A summary of the concept design is as follows:

- 365m long 1100mm high barrier kerb (RMS standard drawing MD.R132.D02.A.1) on concrete footings.
- Located within the existing road shoulder with some minor should improvements.
- Provision is made for a 2.8m wide shoulder between existing road pavement end and proposed barrier, comprising 300mm structure offset, 1m ‘cycle lane’ and 1.5m cyclist buffer.
- A 700mm horizontal zone is allowed for the barrier.
- The barrier is required to transition into existing surface in the west and into the existing embankment in the north east.
- There is expected to be minor requirements for road embankment widening.
- It is assumed that the installation of the levee wall negates the need for a separate crash barrier.
- Fencing has been allowed for.

5.2.3 Constructability

Access
Access is only afforded directly off the existing road verge. There is little space for site compound and laydown areas. Construction plant would be required to be located within the existing road shoulder. Accordingly, road speed limit and lane modifications would be required during construction.

Methodology
The construction methodology would require where practical the use of pre-cast road barrier units to limit installation time. Anticipated temporary lane adjustments would be required to maintain one lane each way. It is assumed that a temporary ‘jersey kerb’ be constructed to segregate the construction zone and road traffic.

Services

Jemena pipe on west side of road, under road verge. Any excavation within the road corridor will need to be mindful of the presence of buried services.

Safety

The following health and safety considerations have been identified for Option B1:

- Safety considerations during construction, with the requirement for working within and adjacent to open roads.
- The introduction of a levee to the south side of the road at The Bends would create a pressurised system during flooding. That is, as water levels elevate during flooding, water levels both sides of the road would increase to up to 1m above road level before overtopping the levees. Such a process would cause rapid inundation of the road once the levees overtopped, as opposed to the current situation in which road inundation occurs gradually.
- Failure of the levee(s) during hydraulic loading would also cause rapid and uncontrolled inundation of the road, potentially posing a greater risk than the above point.
- Increased depth of inundation in some events.

Timeframe

A likely construction timeframe has been estimated at 12 weeks, and is as follows:

- Mobilisation, site setup and environmental controls - 3 weeks
- Construction of road shoulder improvements – 4 weeks
- Construction of levee, shoulder resurfacing and line marking 3 weeks
- Demobilisation 2 weeks.
- **Total – 12 weeks**

The estimated time of road occupancy and traffic control (reduced speed limits) is 6 weeks.

Operation & Maintenance

The structural character of the proposed option would be expected to provide a 50 year design life.

The following operation and maintenance considerations have been identified for Option B1:

- The levee wall would be a passive structure, therefore would not require any additional operational requirements.
- The levee wall would require structural inspection (say once every 5 years) and following moderate flood events, particularly overtopping, as part of Council's or RMS's asset management programme.

5.2.4 Environmental Impacts and Approvals

Construction

The existing floodplain area on the south side of Wakehurst Parkway is potentially important for the protected red-crowned toadlet. Construction of the levee would involve earthworks and construction activities along the southern edge of the road which is adjacent to this habitat and there is potential for direct disturbance of habitat during construction, as well as indirect disturbance. Best practice working methods, that are sensitive to the presence of this habitat, would need to be employed to avoid any potential impact during construction.

As the works would be contained within the road reserve, there is little potential for exposure/release of contaminants. Any material excavated for the levee requiring offsite disposal will need to be waste classified.

Operation

The presence of a levee could potentially affect inundation of the flood plain area to the south and impact on suitability of the habitat for red-crowned toadlet. It is important to note, however, that this area of habitat is located next to a tributary of Middle Creek which would be unaffected by the proposed flood alleviation works and would still allow the regular inundation of this habitat as experienced at present.

Approvals are expected to be dealt with by a Review of Environmental Effects (REF), along with specific construction and road occupancy approvals from RMS.

5.2.5 Impacts on Flooding

Option B1 is estimated to provide flood immunity at The Bends for the 4 EY (3 month ARI) flood event and improve the flood situation for the 2 EY (6 month ARI) flood event (refer **Table 7** below). It should be noted that Option B1 increases flood depths on the road in the 1 EY (1 year ARI) and 0.5 EY (2 year ARI) flood events. Flood impact maps are presented in **Appendix K**.

Table 7: Results of flood modelling and respective road flood immunity for a number of events (Option B1).

Case	Is the road at the Bends flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option B1	N	Y (shallower)	Y (deeper)	Y (deeper)

The road is no longer inundated for the 4 EY (3 month ARI) design event at the Bends. Flood modelling shows a reduced duration of road inundation at the Bends for the 2 EY (6 month), 1 EY (1 year ARI) and the 0.5 AEP (2 year ARI) flood events.

During detailed design, care should be taken to ensure that unidirectional (e.g. flap-gated) road drainage is provided through both levees to drain the road corridor and local drainage at a rate that does not increase the duration of road closure.

5.2.6 Overall Feasibility

No significant feasibility ‘red flags’ have been encountered during the assessment of Option B1. The option is considered to be constructible, however traffic management during construction would be a key consideration.

The option is considered to be feasible, with the primary consideration the approval from RMS for works within the road corridor. There would be a requirement for reduced travel speed limits during the anticipated 6 week (road occupancy) construction period.

Key constraints include space within the existing road corridor to implement the new levee, however this is expected to be achievable with minor road shoulder alterations and temporary lane width reductions. The option presents little environmental impact and could be implemented with minor environmental approvals.

5.3 Option B2

5.3.1 Option Description & Intended Hydraulic Performance

Option B2 comprises construction of a **new levee** at The Bends on the southern side of the road (as discussed in Option B1) together with **removal of an area of overbank sediment** adjacent to the creek. No excavation from within the creek is proposed.

The additional inclusion of the sediment removal aims to improve the general conveyance capacity of the creek and floodplain, as well as removing specific choke points.

5.3.2 Concept Design

A sediment excavation option was developed based on an average of 1m excavation of overbank (floodplain) sediment. The design includes an achievable excavation footprint within the floodplain and riparian zone, as well as enabling works (work areas, access tracks, ramps, etc.). Two points of off-road access are proposed, each with access on/off ramps.

The approximate volume of material to be removed is 28,000m^3. Refer **Appendix I** for concept design plans. It should be noted however that the disturbed footprint (hence that considered for ecological impact assessment) is greater than the corresponding area of sediment extraction, due to the temporary requirement for access ramps and working areas. Due to the low quality of the topographic data used (being LiDAR for the vast majority of the profile), it is highly recommended that detailed topographic survey informs any future design development.

This excavation assumes the full profile is taken out, and that it is acceptable to excavate mixed (not clean sand) materials. If a significant number of trees within the excavation zone at The Bends constriction are to be retained with soil mounds (for tree health and stability), the flooding outcomes may be less favourable due to reduced flow conveyance.

The extent of sediment removal has been proposed to extend upstream of the immediate areas of The Bends. The proposed sediment removal extent has been directed by the findings of the Soil Conservation Service's floodplain sediment characterization, as well refinements to extents based on the practicalities of physical works and inclusion of temporary works areas, such as sorting pads and access ramps (refer **Appendix F**). It should be noted that the extent has been modified from that previously proposed (RHDHV, 2018) and accounted for in contemporary environmental assessments.

The extent of proposed excavation upstream is to provide creek stability and reduce the risk of rapid infill following excavation. The area for vegetation clearance has been selected to avoid the areas of wetland habitat, as far as possible, whilst maintaining benefits for flood alleviation along Wakehurst Parkway.

The removal of sediment would simultaneously involve the removal of vegetation in the same footprint. However, significant trees such as ancient Cabbage Tree Palms could be retained by careful excavation and all disturbed areas would be revegetated following completion of the works. Vegetation removal would be required and replanting would be undertaken with appropriate native species following excavation of sediment.

For reasons of access and safety, it is assumed that turning boxes would need to be constructed to allow for safe truck access and egress, as well as access tracks. Access tracks to the south of the extent require large falls between the road and floodplain.

5.3.3 Impacts on Flooding

Option B2 provides flood immunity at the Bends up to the 2 EY (6 month ARI) flood event and improves flood depths for the 1 EY (1 year ARI) flood event (refer **Table 8** below). Option B2 increases flood depths on the road 0.5 EY (2 year ARI). Flood Maps are presented in **Appendix G**.

Table 8: Results of flood modelling and respective road flood immunity for a number of events (Option B2).

Case	Is the road at the Bends flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option B2	N	N	Y (shallower)	Y (deeper)

The road would no longer be inundated for design flood events up to and including the 2 EY (6 month ARI) at the Bends. Flood modelling predicts a reduced duration of road inundation at the Bends for the 1 EY (1 year ARI) and the 0.5 AEP (2 year ARI) flood event.

During detailed design, care should be taken to ensure that unidirectional (e.g. flap-gated) road drainage is provided through both levees to drain the road corridor and local drainage at a rate that does not increase the duration of road closure.

5.3.4 Constructability

Access

Access points to the overbank areas from the Wakehurst Parkway are restricted by the limited pullover capacity. Road runoff ramps would also need to be constructed. As mentioned above, two points of off-road access are proposed, each with access on/off ramps. Access tracks to the south of the extent require large falls between the road and floodplain. It is assumed that left in left out access would be essential.

Access for plant for the excavation of overbank sediment in the locations proposed would be highly constrained by the lack of access tracks and the dense vegetation. A number of access tracks would need to be constructed off the road, with plant traversing the overbank areas along these paths. Small plant would be required. It is proposed that tracked trucks (such as the Morooka MST-2200 VD) are used to limit the provision of access tracks.

Significant vegetation would need to be cleared. However, this vegetation may need to be disturbed anyway.

There are no appropriate locations at present for site compounds and stockpile areas. Truck parking would need to be in the limited run-off areas, off which site compounds and stockpile areas would be constructed.

Access is considered a significant constraint and would render the vegetation removal and sediment excavation process a laborious and relatively inefficient process, with much vegetation disturbance in addition to the sediment extraction footprint.

Methodology

A preliminary anticipated construction methodology is as follows:

- **Site Setup** - For reasons of access and safety, it is assumed that access ramps and turning boxes would need to be constructed to allow for safe truck access and egress. In addition, internal access tracks would be required.
- Significant **vegetation clearing** would be required. Vegetation clearing in the area has proven not to be a significant issue during the clearing of cross sections for additional topographic survey access. It would be most appropriate for cleared vegetation to be mulched on site and used in re-vegetation.
- **Excavation** - sand pumping, vacuum removal and machine excavation for sediment removal were considered. During the constructability workshop it was determined that sand pumping and vacuum removal were not practical. Machine excavation would be required.
- In places, sediment removal will need to be undertaken in a sensitive manner, as well as likely needing to avoid localised areas, so not to cause excessive environmental impacts. The assumed volume and extent are considered achievable but would need to be confirmed following further studies.
- To avoid the need for extensive access tracks, it is proposed that excavation is undertaken by track excavators and transported to stockpile areas via tracked trucks (such as Morooka MST-2200 VD). The Morooka MST-2200 VD is effectively a tracked tipper with rubber track, which cause no damage to fragile soils and maintain traction on any kind of ground. Use of such vehicles would negate the need for creek crossing infrastructure and substantial access tracks.
- In addition, or alternatively, multi-terrain vehicles such as 40t Moxy or 6t tippers could be used.
- **Sorting** - Sediment is a mix, with high organic content towards the top. There would only be limited opportunity to target excavation of clean sand. It is assumed that excavated material is able to be stockpiled and sorted offsite, then re-used at no cost.
- **Carting offsite –** An excavated volume of 28,000m^3 would require carting off site. At 10m^3 per truck, there would be a requirement for 2,800 truck movements using 12t bogy trucks. Assuming 100 truck movements a day, there would be an estimated 28 days of truck movements. Trucking off site would be preceded by excavation and stockpiling.
- **Material Reuse –** The material has been preliminarily determined as Excavated Natural Material (ENM) (SESL, 2018). It is considered that the overbank material would not be suitable for beach renourishment due to the high organic content, without significant sorting.
- **Re-vegetation** - Replanting would be undertaken with appropriate native species following excavation of sediment.
- **Maintenance –** There would be a requirement for intensive maintenance of approximately 2.4 hectares of revegetation.

Safety

The following health and safety considerations have been identified for the removal of overbank sediment:

- The removal of overbank sediment will require extensive periods of working close to the creek and within the floodplain. Construction health and safety with regard to flood risk therefore is a significant consideration.
- The ongoing need for people to be undertaking vegetation management within the creek and floodplain.

- The significant amount of work can be undertaken offline of the road network, including vegetation removal, excavation, sediment sorting and replanting. However, the above-mentioned truck movements will require significant traffic management.
- This would likely require periods of reduced speed limit for working times throughout the trucking period (5 weeks).
- In addition, daily access to the site for workers will require initial pull in zones.

Services

There are no significant considerations with regard to services.

Timeframe

A likely construction timeframe has been estimated at 27 weeks, and is as follows:

- Site setup - 1 week
- Environmental controls – 1 week
- Vegetation clearing and stockpiling – 4 weeks
- Vegetation carting offsite – 1 week
- Construction of access tracks – 1 week
- Sediment excavation, sorting and stockpiling – 125 Days (25m^3 / hour, 119 days (17 weeks))
- Trucking 5 weeks + 2 weeks contingency (23,800m^3 – 10m^3 per truck, 100 truck movements a day. 23 days (5 weeks) of truck movements). Concurrent to excavation.
- Revegetation – 6 weeks.
- Demobilisation 2 weeks.
- **Total – 33 weeks**

Operation & Maintenance

The following operation and maintenance considerations have been identified for Option B2, in addition to those identified for Option B1:

- The removal of overbank sediment and associated clearing of vegetation would require a relatively long and extensive re-vegetation programme and ongoing maintenance.

The structural elements of the proposed option (the levee) would be expected to provide a 50 year design life. The nature of sediment removal and the potential for sediment infill is a key consideration. The removal of sediment from upstream of The Bends is proposed to limit influx from the sediment layer upstream, as per recommendations made in Pietsch and Soil Conservation Services (2018). Regardless, the option presents the need of ongoing vegetation management.

5.3.5 Environmental Impacts and Approvals

Environmental impacts and required approvals associated with Option B2 are summarised below and presented in full in **Appendix E**.

Assessment and Approvals

Self-determining authorities such as Northern Beaches Council can assess impacts of Part 5 developments on threatened biota listed under the BC Act via Part 7 of the BC Act.
An assessment of significance (5 part Test) must be prepared for those threatened biota that have the potential to be impacted by the proposal. If a significant impact is likely, then either a Species Impact Statement (SIS) or a Biodiversity Development Assessment Report (BDAR) must be prepared.

Alternatively, the self-determining authority can decide to ‘opt into’ the BDAR or SIS once a Assessment of Significance has been undertaken.

Impacts to threatened biota listed on the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) would need to be addressed in the reports and referred to the Commonwealth if a significant impact is likely.

Vegetation Impacts

Based on the mapping provided and the validated GHD vegetation mapping and existing vegetation mapping, the direct disturbance to native vegetation is 2.41 ha. A further 0.45 ha of non-native vegetation would be impacted.

No TECs listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) would be impacted by the Project.

A 5-Part Test under the BC Act has not been completed for the impacts to 2.30 ha of Swamp Sclerophyll Forest TEC. However, it is likely that a significant impact to this TEC would occur.

Given the likely significant impacts to Swamp Sclerophyll Forest TEC, either a SIS or BDAR would need to be prepared and thus require offsetting for impacts to native vegetation, and threatened biodiversity regarded as ‘species credits’.

It is possible that a significant impact to the Red-crowned Toadlet, Large-eared Pied Bat, Southern Myotis and Giant Burrowing Frog may also occur given the impact to 2.41 ha of habitat and indirect impacts to the species.

Indirect impacts are not known at this stage and would need to be incorporated in the impact assessment for the project.

Environmental offsetting would likely be required for

- PCT659 Bangalay - Old-man Banksia open forest on coastal sands, Sydney Basin Bioregion and South East Corner Bioregion
- PCT781 Coastal freshwater lagoons of the Sydney Basin and South East Corner
- PCT1841 Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region
- Red-crowned Toadlet habitat
- Giant Burrowing Frog habitat
- Southern Myotis habitat
- Large-eared Pied Bat habitat

Key Assumptions

1. Environmental Impacts will be accepted.
2. Offset credit values are at today’s rates. It should be noted that these rates are changed every 3 months.
3. There was a possible animal den sighting by SCS personnel, with the likely inhabitant remaining unidentified (water rat, platypus, etc). To date, requested information (location) have not been provided. Although not listed, this species is iconic and therefore may have public perception implications. In addition, a plan for relocation is likely.

5.3.6 Overall Feasibility

Access is considered a significant constraint and would turn the vegetation removal and sediment excavation process into a laborious and relatively inefficient process. There would be the need to create off road corridor site compounds, access tracks and loading areas. Small plant would be required for excavation.

In addition, many trucks needing to pull in and off the road presents a significant safety issue. There would be an estimated truck movement period of 6 weeks, comprising 100 truck movements per day.

The option does not require any physical works within the road corridor, however would require significant road traffic management, hence RMS approval.

Environmental impacts are anticipated to be significant and the option implementation would be subject to significant additional environmental assessment and approvals. The total construction timeline is anticipated to exceed 28 weeks, not including the revegetation maintenance period. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or an SIS, as well as a Biodiversity Management Plan.

5.4 Option B3

5.4.1 Option Description & Intended Hydraulic Performance

Option B3 comprises construction of a **new levee** at The Bends (as per Option B1), **removal of overbank sediment** (including vegetation) (as discussed in Option B2), with the addition of two sets of **new culverts under the road**.

The additional inclusion of the culverts aims to improve the conveyance of flow from within the creek to the southern floodplain, maximising floodplain conveyance and storage.

5.4.2 Concept Design

For the purposes of this assessment, the following concept design elements have been assumed for the culverts (the levee and sediment excavation are discussed elsewhere):

- two (2) culvert banks would be constructed with pre-cast concrete box culvert units and base slab;
- 9 x 900H x 2700W RCBC with link slabs (constructed to AS1597.2-2013);
- The two culvert banks would have similar inverts as the existing culverts;
- Concrete headwalls and rock scour protection would be required, with appropriate tail out channels;
- There will be a requirement for excavation on the eastern floodplain to form tail-outs, to account for increased flows; and
- a pad or ramped access to the culverts for maintenance and blockage removal to take place.

For concept design sketches of Option B3 please refer to **Appendix J.**

The size and extent of the culvert banks may warrant consideration for bridges, as an alternate approach.

5.4.3 Impacts on Flooding

Option B3 provides flood immunity at the Bends up to the 1 EY (1 year ARI) flood event and improves the flood situation for the 0.5 EY (2 year ARI) flood event (refer **Table 9** below). Flood Maps are presented in **Appendix K**.

Table 9: Results of flood modelling and respective road flood immunity for a number of events (Option B3).

Case	Is the road at the Bends flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option B3	N	N	N	Y (shallower)

The road is no longer inundated for design events up to and including the 1 EY (1 year ARI) at the Bends. Flood modelling shows a reduced duration of road inundation at the Bends 0.5 AEP (2 year ARI) event. During detailed design, care should be taken to ensure that unidirectional (e.g. flap-gated) road drainage is provided through both levees to drain the road corridor and local drainage at a rate that does not increase the duration of road closure.

5.4.4 Constructability

Constructability of the culverts is discussed below. See Option B1 and option B2 for discussion of other elements, such as new levee and sediment extraction.

Access

- The inherent nature of the culverts being under the road require direct access to the road.
- There is little access either side of the culverts to construct from an off-road position or shoulder.
- Access for construction is limited, with little room for construction plant and site compound.
- The inability to close the road completely limits access. Road occupancy is suggested to include a temporary jersey barrier between the road and works area.
- Access is considered to be best achieved by constructing a temporary road widening along the northern shoulder, with associated works to the creek to maintain flow conveyance.

Methodology

- The most likely construction method would be open-cut trench through the road and backfilled to restore the road pavement surface. Culvert units can therefore be placed directly following excavation and foundation improvements.
- Thrust boring was considered, however, discounted due to the space requirements at either end of the culverts (see minutes form Constructability Workshop).
- The limited space available for plant and working areas would require double handling of culvert units.
- It is considered unacceptable to close the road during construction (communicated by Council during constructability workshop). It is therefore required and expected that the road would temporarily be widened locally to allow for only partial road opening and allowing continuity of traffic flow (continuous two lanes).
- To provide two lanes, the road will require to be widened locally. This would be achieved via a berm constructed along the northern side of the road, between the existing levee and the creek.
- Works would then be undertaken in the southern culverts, working back along the access track, removing as you go.
- At each culvert crossing, the following actions would be required:
    - Close road
    - Excavate and shore
    - Prepare foundations
    - Place culverts
    - Backfill
    - Form pavement
- The need for reduced lane widths is likely.
- The need for temporary speed limit reductions are almost certain.
- Night working would not be expected to significantly reduce impacts to traffic, as the reduced lane widths will require a speed limit throughout the works.
- There is a significant need for disposal off site of excavated material – primarily road fill, however potentially some ASS.

As mentioned above, the size and extent of the culvert banks may warrant consideration for bridges, as an alternate approach.

Services

There is a sewer pipe down the centre of road. DBYD indicated 0.7m cover. A Jemena pipe is located on the west side of road, under road verge.

Depending on the depth of both the sewer and gas mains that are generally aligned parallel with the road, the construction of the new culverts has the potential to interact with both services. However, as there are existing pipes under the road, the services conduit depths are assumed to be sufficient to avoid direct conflicts. More likely is the need for consideration during construction and maybe temporary and / or permanent services protection measures, such as bridging slabs or concrete encasement. Regardless, both these services will be required to be protected during construction.

Safety

The following health and safety considerations have been identified:

- The anticipated road closures and traffic management pose a risk to both construction personnel and the general public.
- There are no additional health and safety implications foreseen for the general public following construction.
- The ongoing need for people to be undertaking culvert maintenance and sedimentation management within the road corridor poses an operational consideration.

Timeframe

A likely construction timeframe has been estimated and is as follows:

- site setup including environmental controls and traffic management - 1 week
- construction of localised road widening – 5 weeks
- excavation of road and placement of southern culverts (1 week per side) – 6 weeks – down to 40 k/h
- remove southern section of access track – 4 weeks
- excavation of road and placement of southern culverts (1 week per side) – 6 weeks – down to 40 k/h
- demobilisation 1 week.
- **Total** – 23 weeks

Operation & Maintenance

The following operation and maintenance considerations have been identified for Option B3, in addition to those stated above for Option B1 and B2:

- The structural aspects of the proposed option (levee, culverts) would be expected to provide a 50 year design life if designed and constructed correctly.
- The culverts are passive structures therefore would not require any operation.
- Routine (1/2 times every year and after moderate rain events) inspection of the culverts would be required to ensure no blockage and would be recommended as part of Council's or RMS's asset management programme.

- Should the culverts become partially blocked with sediment or other debris, then there would be a need to clear the blockage to ensure functionality.

5.4.5 Environmental Impacts and Approvals

Environmental Impacts and Permits

Key environmental constraints for this option are:

- Proximity to red-crowned toadlet habitat.
- Potential for direct impact on EEC habitats adjacent to Middle Creek.
- Vegetation clearance within the Oxford Falls Landscape Conservation Area.
- Risk of exposing acid sulphate soils.
- Appropriate disposal of cleared sediment.
- Ongoing management of cleared vegetation.

Key environmental benefits for this option are:

- No direct clearance of sediments from within the creek channel, which would avoid potential impacts to fish habitat.
- Some areas where vegetation may need to be cleared is mapped as non-native weeds. Removal of these species and replanting with native species is potentially beneficial.

Construction

The existing floodplain area on the south side of Wakehurst Parkway is potentially important for the protected red-crowned toadlet. Construction of the levee and culverts would involve earthworks along the southern edge of the road which is adjacent to this habitat and there is potential for direct disturbance of habitat during construction. Best practice working methods, that are sensitive to the presence of this habitat, would need to be employed to avoid any potential impact during construction.

Clearance of vegetation would be required for the removal of sediment. The habitats that would primarily be affected are Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and Southeast Corner Bioregions and Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and Southeast Corner Bioregions.

There is a risk that excavation of sediment below the road fill surface, to construct the culvert and bedding, could expose acid sulphate soils (ASS). Northern Beaches Council mapping shows that some soils in the area of proposed sediment removal are listed as 'Class 3 – ASS likely to be present 1m below the natural ground surface'. This is below the likely depth of excavation required for construction of the culverts however ground investigations and soils testing, in accordance with the ASS Manual, would need to be undertaken to confirm the soil classification and ensure there is no risk of uncovering ASS from the proposed works. SESL (2018) recommends that the proposed excavation works must be managed under the site-specific Acid Sulfate Soil Management Plan (ASSMP).

Operation

The installation of new culverts will affect the inundation regime of the floodplain area to the south and potentially impact on suitability of the habitat for red-crowned toadlet. Modelling work will need to be undertaken to look at new flow regimes and any increased levels of inundation in the area to assess potential impacts to habitat.

Removal of vegetation has the potential to increase sedimentation downstream at Narrabeen Lagoon potentially impacting on water quality there through increased turbidity and settling of sediments.

It is unclear if biodiversity offsetting would be required, as no Assessments of Significance have been completed as part of this assessment. However, it seems likely that based on the area of direct and indirect impacts associated with Option B3, that a significant impact may be concluded. Environmental Vegetation impacts consist of the following:

- Direct impacts due to sediment removal works, consisting of direct disturbance to native vegetation and habitat of 2.41 ha, as per Option B2 including:
    - Impacts to approximately 2.3 ha of Swamp Sclerophyll Forest TEC.
    - Impacts to approximately 0.06 ha of Freshwater Wetlands on Coastal Floodplains TEC.
    - Impacts to approximately 0.05 ha of Smooth-barked Apple - Turpentine - Blackbutt tall open forest (not listed).
    - Impacts to approximately 2.41 ha of Red-crowned Toadlet habitat.
    - Impacts to approximately 2.41 ha of Giant Burrowing Frog habitat (note this needs to be confirmed via targeted survey).
    - Impacts to approximately 2.41 ha of Southern Myotis habitat.
    - Impacts to approximately 2.41 ha of Large-eared Pied Bat habitat.
- Indirect impacts to native vegetation and habitat of 0.22 ha (minimum), due to culvert works, consisting of (at a minimum assuming 5m culvert tail-in and tail-out):
    - Impacts to approximately 0.15 ha of Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions TEC.
    - Impacts to approximately 0.04 ha of Freshwater Wetlands on Coastal Floodplains TEC.
    - Impacts to approximately 0.02 ha of Swamp Sclerophyll Forest TEC.
    - Impacts to approximately 0.22 ha of Red-crowned Toadlet habitat.
    - Impacts to approximately 0.22 ha of Powerful owl foraging habitat.
    - Impacts to approximately 0.22 ha of Bittern habitat.

5.4.6 Overall Feasibility

In addition to Option B2 (new levee and floodplain sediment removal), the addition of under road culverts significantly increases the disturbance footprint, capital works and presents significant temporary road closure / partial closures. The option is considered to be constructible through open trench methods, whilst maintaining two-way traffic.

Appropriate staging and traffic management would need to be considered to limit road closures during culvert construction. Some form of partial or full temporary road closure would be expected.

The disturbance to sensitive and valuable habitat east of the road by culvert tail out channels is anticipated to cause significant environmental impacts. There is an estimated environmental offset cost of $738k (excl. GST) for the option as a total. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or an SIS, as well as a Biodiversity Management Plan.

5.5 Option B4

5.5.1 Option Description & Intended Hydraulic Performance

This option would comprise a **new levee** (southern levee) at The Bends, **removal of overbank sediment** (including vegetation) and **installation of culverts** under the road (as discussed in Option B3), with the addition of **topping up the existing northern levee**.

Option B4 (this option) differs from Option B3 with only the topping up the existing northern levee.

The topping up of the northern levee provides a consistent crest level of the levee (relative to the water profile) and removes the existing low points.

5.5.2 Concept Design

The approach to the concept design of the top up of the northern levee would be consistent with option B1, i.e. a new concrete barrier.

- 1100mm HIGH BARRIER KERB (RMS STD DRAWING MD.R132.D02.A.1)
- Located within the existing road shoulder
- Provision is made for a 2.8m wide shoulder between existing pavement and barrier, comprising 300mm structure offset, 1m cycle lane and 1.5m cyclist buffer.
- A 700mm horizontal zone is allowed for the barrier.
- The barrier is required to transition into existing surface at each terminal.

For concept design sketches of Option B4 please refer to **Appendix J.**

5.5.3 Impacts of Flooding

Option B4 provides flood immunity at the Bends up to the 0.5 EY (2 year ARI) flood event (refer **Table 10** below). Flood Maps are presented in **Appendix K**.

Table 10: Results of flood modelling and respective road flood immunity for a number of events (Option B4).

Case	Is the road at the Bends flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option B4	N	N	N	N

The road is no longer inundated for design events up to and including the 0.5 EY (2 year ARI) at the Bends.

5.5.4 Constructability

No different to Option B3.

5.5.5 Environmental Impacts and Approvals

No different to Option B3.

5.5.6 Overall Feasibility

In addition to Option B3 (new levee, floodplain sediment removal and road culverts), the additional works associated with the existing levee top up are considered relatively minor. Option B4 can therefore be considered similar to Option B3 in many aspects, whilst providing significant additional flood benefits.

The option is estimated to cost $13.8M (excl. GST) and, similarly to Option B4, the implementation would be subject to significant additional environmental assessment and approvals. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or an SIS, as well as a Biodiversity Management Plan.

5.6 Option B5

5.6.1 Option Description & Intended Hydraulic Performance

This option would involve the removal of an area of overbank sediment only, as per Option B2, B3 and B4 above.

5.6.2 Concept Design

For the purposes of this assessment, the conceptual design and the feasibility assessment of the sediment removal for Option B5 is as described initially above for Option B2.

5.6.3 Impacts on Flooding

Option B5 provides flood immunity at the Bends up to the 4 EY (3 month ARI) flood event (refer **Table 11** below). The flood level within Middle Creek, adjacent to the Bend delivers approximately 260mm of peak flood level reduction for the 3month, 12hr event, and hence it does not overtop the road for this design case. There is a decrease in duration of road inundation for the 2 EY (6 month ARI) to the 0.5 EY (2 year ARI) flood event. Flood Maps are presented in **Appendix G**.

Table 11: Results of flood modelling and respective road flood immunity for a number of events (Option B5).

Case	Is the road at the Bends flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option B5	N	Y	Y	Y

5.6.4 Environmental Impacts and Approvals

For the purposes of this assessment, environmental impacts and approvals for the sediment removal for Option B5 is as described initially above for Option B2.

5.6.5 Overall Feasibility

The option does not require any physical works within the road corridor, however would require significant road traffic management, hence RMS approval. The option requires significant physical works outside the road corridor and would require significant road traffic management. The total construction timeline is anticipated to exceed 25 weeks.

Key constraints include access, existing valuable habitat, traffic management and the need to dispose of excavated material.

Environmental impacts are anticipated to be significant. Significant environmental offset cost is estimated at $671k (excl. GST).

Flood Impacts are minor positive. Flood immunity up to 4 EY (3 month ARI).

The option is estimated to cost $4.M (excl. GST) and the implementation would be subject to significant additional environmental assessment and approvals. Council will be required to complete a Biodiversity Development Assessment Report (BDAR) or an SIS, as well as a Biodiversity Management Plan.

5.7 Option B6

5.7.1 Option Description & Intended Hydraulic Performance

This option would involve the removal of an area of overbank sediment only with a similar extent of Option B5 above (also as per Options 2, 3 and 4 above), but to an increased depth of 2m.

5.7.2 Concept Design

For the purposes of this assessment, the conceptual design of the sediment removal for Option B6 is as described above for Options B5, but with the additional removal of 1 m depth of sediment, i.e., to 2 m depth in total.

The resulting volume of sand to be removed is estimated as 51,200m^3.

5.7.3 Impacts on Flooding

Option B6 provides flood immunity at the Bends up to the 4 EY (3 month ARI) flood event, with 1 lane flood free in the 2 EY (6 month ARI) flood event (refer **Table 12** below). Flood Maps are presented in **Appendix G**.

Table 12: Results of flood modelling and respective road flood immunity for a number of events (Option B6).

Case	Is the road at the Bends flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option B6	N	Y, 1 lane	Y	Y

The road is no longer inundated for the 4 EY (3 month ARI) at the Bends.
There is a decrease in duration of road inundation for the 2 EY (6 month ARI) to the 0.5 EY (2 year ARI) flood event.

5.7.4 Overall Feasibility

The option is considered **unfeasible**. The creek is typically less than 1m below the overbank area, therefore the proposed 2m of floodplain excavation would result in significant lowering of the existing creek, resulting in an imbalance in the fluvial regime, as well as ponding. In addition, the entire vegetation and habitat would change and not able to be readily rehabilitated.

5.8 Option B7

5.8.1 Option Description & Intended Hydraulic Performance

This option would involve construction of the southern levee at The Bends and installation of culverts under the road (as discussed in Option B3).

5.8.2 Concept Design

For concept design sketches of Option B7 please refer to **Appendix F.**

5.8.3 Impacts of Flooding

Option B7 provides flood immunity at the Bends up to the 1 EY (1 year ARI) flood event (refer **Table 10** below). Flood Maps are presented in **Appendix G**.

Table 13: Results of flood modelling and respective road flood immunity for a number of events (Option B7).

Case	Is the road at the Bends flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3-month ARI)	2 EY (6-month ARI)	1 EY (1-year ARI)	0.5 EY (2-year ARI)
Existing	Y	Y	Y	Y
Option B7	N	N	N	Y

The road is no longer inundated for design events up to and including the 1 EY (1-year ARI) at the Bends.

5.8.4 Overall Feasibility

This option provides a feasible alternative to Option B3, due to the high level of flood performance without the need for sediment removal.

The under-road culverts require a significant disturbance footprint, capital works and presents significant temporary road closure / partial closures. The option is considered to be constructible through open trench methods, whilst maintaining two-way traffic.

The disturbance to sensitive and valuable habitat east of the road by culvert tail out channels is anticipated to cause significant environmental impacts. There is an estimated environmental offset cost of $67k (excl. GST).

The option is estimated to cost $8.1M (excl. GST) and the implementation would be subject to significant additional environmental assessment and approvals.

The option does not address the ongoing issue of creek and floodplain sedimentation, and the resulting flood impacts.

5.9 Option O1

5.9.1 Option Description & Intended Hydraulic Performance

Option O1 comprises the amplification of the two (2) existing road pipe crossings under the Parkway at Oxford Falls at two locations. The aim of this option is to increase the conveyance of flood water under the road and contain water within the channel.

5.9.2 Concept Design

It is assumed that the pipes would be constructed by an open trench excavation. The existing northern crossing (2 x 1.8m diameter pipes) would be replaced by 3 x 1.8m diameter pipes (one additional pipe). The existing southern crossing (1 x 0.375m diameter pipe) would be replaced by 3 x 0.6m diameter pipes (two additional pipes)

Although the option involves additional pipes, it is expected and therefore assumed that the existing pipes would be replaced, whilst the trenches are open.

For concept design sketches of Option O1 please refer to **Appendix J**.

The structural nature of the proposed option would be expected to provide a 50 year design life.

5.9.3 Impacts on Flooding

Option O1 provides flood immunity of the road at the culvert crossing for flood events up to the 1 EY (1 year ARI) flood event (refer **Table 14** below). Flood Maps are presented in **Appendix K**.

Table 14: Results of flood modelling and respective road flood immunity for a number of events (Option O1).

Case	Is the road flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option O1	N	N	N	Y

The road is no longer inundated for design events up to and including the 1 EY (1 year ARI) at Oxford Falls.
There is a decrease in duration of road inundation for the 0.5 EY (2 year ARI) flood event.

5.9.4 Constructability

Health & Safety
The following health and safety considerations have been identified for Option O1:

- The anticipated road closures and traffic management pose a risk to both construction personnel and the general public.
- There are no additional health and safety implications for the general public following construction.

- The ongoing need for people to be undertaking pipe maintenance and sedimentation management within the road corridor poses an operational consideration but is similar to current regimes.

Operation & Maintenance
The following operation and maintenance considerations have been identified for Option O1:

- The pipes are passive structures therefore would not require any operation.
- Routine (1/2 times every year and possibly after moderate rain) inspection of the culverts would be required to ensure no blockage and would be recommended as part of Council's or RMS's asset management programme.
- Should the pipes become partially blocked with sediment, then there would be a need to clear the blockage.

Existing Services
At Oxford Falls Road, a sewer main runs parallel to Middle Creek. The sewer pipe is not located in the road footprint, therefore is not expected to conflict with the potential works of Option O1.

There are Telstra services contained within the road corridor south of the southern set of pipes. These do not appear to cross the existing pipes, therefore are not expected to conflict with potential works.

The Optus underground cable, located within the road corridor, would be impacted by the potential works. It is assumed that the buried cable runs over the top of the existing pipes each of the two crossings. This cable would require protecting, or more likely temporary realignment during construction.

5.9.5 Environmental Constraints

Option O1 seems less likely to result is significant impacts due to the following:

- Only 0.07 ha of native vegetation and habitat would be direct impacted.
- It is unlikely that any TECs would be impacted.
- No Red-crowned Toadlet habitat has been mapped within the site
- No threatened flora or fauna have been recorded within the site.

5.9.6 Overall Feasibility

No significant 'red flags' have been encountered during the assessment.

There would be the need for full or partial road closures during construction, however it is anticipated that such partial road closure could be undertaken whilst maintaining 2 lanes of flowing traffic (one each way), albeit at a reduced speed temporarily.

The buried Optus cable would require protecting or temporary realignment during construction.

5.10 Option O2

5.10.1 Option Description & Intended Hydraulic Performance

Option O2 comprises the further amplification of the two existing road culvert crossings under the Parkway per Option O1 above, although for Option O2 the pipe augmentations provide 0.5 EY (2 year ARI) immunity from road flooding. The aim of this option is to increase the conveyance of flood water under the road and contain water within the channel within a 0.5 EY (2 year ARI) flood event.

5.10.2 Concept Design

It is assumed that the pipes would be constructed by an open trench excavation.

The existing southern pipes (2 x 1.8m diameter pipes) would be replaced by 4 x 1.8m diameter pipes (one additional pipe). The existing northern crossing (1 x 0.375m diameter pipe) would be replaced by 6 x 0.6m diameter pipes (five additional pipes).

Although the option involves the addition of one pipe, it is expected and therefore assumed that the two existing pipes would be replaced, whilst the trench is open.

For concept design sketches of Option O2 please refer to **Appendix J**.

The structural nature of the proposed option would be expected to provide a 50 year design life.

5.10.3 Environmental Impacts

Option O2 seems less likely to result is significant impacts due to the following:

- Only 0.07 ha of native vegetation and habitat would be direct impacted.
- It is unlikely that any TECs would be impacted.
- No Red-crowned Toadlet habitat has been mapped within the site
- No threatened flora or fauna have been recorded within the site.

5.10.4 Impacts on Flooding

Option O2 provides flood immunity of the road at the culvert crossing for flood events up to the 0.5 EY (2 year ARI) flood event as designed (refer **Table 15** below). Flood Maps are presented in **Appendix K**.

Table 15: Results of flood modelling and respective road flood immunity for a number of events (Option O2).

Case	Is the road flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	Y	Y	Y	Y
Option O2	N	N	N	N

The road is no longer inundated for design events up to and including the 0.5 EY (2 year ARI) at the Bends.

5.10.5 Overall Feasibility

No significant ‘red flags’ have been encountered during the assessment.

There would be the need for full or partial road closures during construction, however it is anticipated that such partial road closure could be undertaken whilst maintaining 2 lanes of flowing traffic (one each way), albeit at a reduced speed temporarily.

The buried Optus cable would require protecting or temporary realignment during construction.

5.11 Option S1

5.11.1 Option Description & Intended Hydraulic Performance

Option S1 comprises the provision of two bunds adjacent to the **Sydney Academy of Sport and Recreation**, to restrict the movement of overland flow across the low point of Wakehurst Parkway.

5.11.2 Concept Design

Due to space constraints, the levee is considered to be best constructed using a bund wall to limit the footprint and contain the works to within the road corridor, similar to Option B1. There is not considered sufficient space for a more conventional earth embankment. A design has been developed to RMS standards using a concrete barrier.

For concept design sketches of Option S1 please refer to **Appendix J**.

The structural elements of the proposed option would be expected to provide a 50 year design life.

A summary of the concept design is as follows:

- 1100mm high barrier kerb (RMS standard drawing MD.R132.D02.A.1) on concrete footings.
- Located within the existing road shoulder with some minor should improvements.
- Provision is made for a 2.8m wide shoulder between existing road pavement end and proposed barrier, comprising 300mm structure offset, 1m ‘cycle lane’ and 1.5m cyclist buffer.
- A 700mm horizontal zone is allowed for the barrier.
- The barrier is required to transition into existing surface in the west and east.
- There is expected to be minor requirements for road embankment widening.
- It is assumed that the installation of the levee wall negates the need for a separate crash barrier.

5.11.3 Constructability

Access
Access is only afforded directly off the existing road verge. There is little space for site compound and laydown areas. Construction plant would be required to be located within the existing road shoulder. Accordingly, road speed limit and lane modifications would be required during construction.

Methodology
The construction methodology would require where practical the use of pre-cast road barrier units to limit installation time. Anticipated temporary lane adjustments would be required to maintain one lane each

way. It is assumed that a temporary 'jersey kerb' be constructed to segregate the construction zone and road traffic.

Services
Jemena pipe on west side of road, under road verge. Any excavation within the road corridor will need to be mindful of the presence of buried services.

Safety
The following health and safety considerations have been identified for Option S1:

- Safety considerations during construction, with the requirement for working within and adjacent to open roads.
- The introduction of a levee would create a pressurised system during flooding. That is, as water levels elevate during flooding, water levels both sides of the road would increase to up to 1m above road level before overtopping the levees. Such a process would cause rapid inundation of the road once the levees overtopped, as opposed to the current situation in which road inundation occurs gradually.
- Failure of the levee(s) during hydraulic loading would also cause rapid and uncontrolled inundation of the road, potentially posing a greater risk than the above point.
- Increased depth of inundation in some events.

Timeframe
A likely construction timeframe has been estimated at 4 weeks, and is as follows:

- Mobilisation, site setup and environmental controls - 3 weeks
- Construction of road shoulder improvements – 3 weeks
- Construction of levee, shoulder resurfacing and line marking 3 weeks
- Demobilisation 2 weeks.
- **Total – 11 weeks**

The estimated time of road occupancy and traffic control (reduced speed limits) is 6 weeks.

Operation & Maintenance
The structural character of the proposed option would be expected to provide a 50 year design life.

The following operation and maintenance considerations have been identified for Option B1:

- The levee wall would be a passive structure, therefore would not require any additional operational requirements.
- The levee wall would require structural inspection (say once every 5 years) and following moderate flood events, particularly overtopping, as part of Council's or RMS's asset management programme.

5.11.4 Environmental Impacts

Works within the road corridor would not require offsets. Due to localised drainage impacts, works within the adjacent channel may be required to improve local drainage, and if so biodiversity offsetting would be required due to the following disturbance footprint:

- Impacts to approximately 0.74 ha of Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions TEC.
- Impacts to approximately 0.04 ha of Freshwater Wetlands on Coastal Floodplains TEC.
- Impacts to approximately 0.74 ha of Red-crowned Toadet habitat
- Impacted to approximately 0.74 ha of Powerful owl foraging habitat
- Impacts to approximately 0.74 ha of Black Bittern habitat.
- Impacts to approximately 0.74 ha of Glossy Black Cockatoo habitat.

5.11.5 Impacts on Flooding

This option achieves the 0.5 EY (2 year ARI) flood immunity of the road (refer **Table 16** below). Flood Maps are presented in **Appendix K**.

Table 16: Results of flood modelling and respective road flood immunity for a number of events (Option S1).

Case	Is the road flooded from the Creek in the stated event? (Excluding local effects from direct rainfall on road with poor drainage)			
	4 EY (3 month ARI)	2 EY (6 month ARI)	1 EY (1 year ARI)	0.5 EY (2 year ARI)
Existing	N	N	N	Y
Option S1	N	N	N	N

5.11.6 Overall Feasibility

No significant ‘red flags’ have been encountered during the assessment, however the risk of blockage and flooding from local runoff is high if this option is implemented, hence the ‘do nothing’ case may be considered preferable.

5.12 Summary of Feasibility Assessment

*A summary of the feasibility assessment is presented below in **Table 17** to*

***Table 19**.*

Table 17: Multi-Criteria Analysis, flood mitigation options for The Bends

Assessment Criteria	Option B1	Option B2	Option B3	Option B4	Option B5	Option B6	Option B7
Environmental Constraints	No significant impact expected	Significant Impacts	Significant Impacts	Significant Impacts	Significant Impacts	Significant Impacts	Significant Impacts
Approximate Area of Native Vegetation Impacted	Insignificant	2.41 ha	2.63 ha (2.41 ha + 0.22* ha)	2.63 ha (2.41 ha + 0.22* ha)	2.41 ha		0.22* ha
Impact to Services and Utilities	None expected	None expected	Potential conflicts with services / need for protection	Potential conflicts with services	None expected	None expected	Potential conflicts with services
Maintenance	Low: Routine inspection.	Ongoing maintenance. Vegetation and channel.	Ongoing maintenance. Vegetation and channel.	Routine maintenance of new culverts to prevent debris build up and blockage. Ongoing maintenance. Vegetation and channel.	Ongoing maintenance. Vegetation and channel.	Ongoing maintenance. Vegetation and channel.	Routine maintenance of new culverts to prevent debris build up and blockage. Ongoing maintenance.
Health & Safety	Construction safety with traffic. Public safety risk reduced	Construction safety with traffic. Public safety risk reduced	Construction safety with traffic. Public safety risk reduced	Construction safety with traffic. Public safety risk reduced	Construction safety with traffic. Public safety risk reduced	Construction safety with traffic. Public safety risk reduced	Construction safety with traffic. Public safety risk reduced
Construction Feasibility	No significant ‘red flags’. Moderate; work within road reserve.	Difficult; overbank sediment excavation.	Difficult; overbank sediment excavation. Temporary road closures for culverts.	Difficult; overbank sediment excavation. Temporary road closures for culverts.	Difficult; overbank sediment excavation.	**Not feasible**	Moderate; Temporary road closures for culverts. Work within road reserve.
Costs (excl. GST)	$2M	$5.8M	$12.1M	$13.8M	$4.1M	-	$8.1M

* 0.22 ha for 5 m culvert tail-in and tail-out. This area may increase up to 0.44 ha if larger tail-outs required.

Table 18: Multi-Criteria Analysis, flood mitigation options for Oxford Fall Road

Assessment Criteria	Option O1	Option O2
Environmental Constraints	No significant impact expected	No significant impact expected
Approximate Area of Native Vegetation Impacted	0.07 ha	0.07 ha
Impact to Services and Utilities	None expected. Services protection required during construction	None expected. Services protection required during construction
Maintenance	Low: Routine maintenance of new culverts to prevent debris build up and blockage.	Low: Routine maintenance of new culverts to prevent debris build up and blockage.
Health & Safety	Construction safety with traffic. Public safety risk reduced	Construction safety with traffic. Public safety risk reduced
Construction Feasibility	Moderate; Temporary road closures for culverts	Moderate; Temporary road closures for culverts
Costs (excl. GST)	$1.2M	$1.6M

Table 19: Multi-Criteria Analysis, flood mitigation options for Academy of Sport

Assessment Criteria	Option S1
Environmental Constraints	No significant impact expected unless concurrent local drainage improvements required.
Approximate Area of Native Vegetation Impacted	0 ha (0.74 ha if local drainage improvements required)
Impact to Services and Utilities	None expected. Services protection required during construction
Maintenance	Medium: Routine maintenance of new flap-gate drainage pipes to prevent debris build up and blockage.
Health & Safety	Construction safety with traffic. Public safety risk reduced. Increased risk of drainage issues from pipe blockage.
Construction Feasibility	Moderate; Temporary road closures for culverts. Land ownership Issues.
Costs (excl. GST)	$2.1M

6 Residual Risks

Residual risks for option implementation include:

- The impact of localised pluvial flooding (ponding) remains a risk for options comprising levee construction or raising.
- further ongoing sediment infill and choking of the creek corridor could continue for options not including sediment removal. Further sedimentation could exacerbate the existing flooding issue.
- environmental approvals and the need for further assessment is required, primarily for sediment removal and road culvert options (at The Bends). Environmental impacts may not be considered acceptable.
- offset credit values are estimated at today's rates. It should be noted that these rates are changed every 3 months.
- RMS approvals regarding traffic management (for options outside the road corridor) or road closures and occupancy (for options within the road corridor) would be required. It is understood that limited consultation with RMS has taken place to date.
- the sediment contamination testing undertaken to inform this assessment was limited. To fully classify the sediment prior to removal would require significant additional testing. Should additional testing change the waste classification, then estimated disposal costs would increase significantly, and likely render the option unfeasible due to costs.
- In the case of options involving sediment excavation, it has been assumed that excavated sediment (to be disposed of offsite)) is able to be beneficially reused elsewhere.
- There remains a number of uncertainties regarding land ownership.
- Options have been tested based on present day conditions, including rainfall, site constraints and baseline environmental conditions. The present study has not taken account of climate change (potential increase in rainfall intensity) or sea level rise.
- A European Heritage Assessment has not been undertaken.

7 Conclusions and Recommendations

7.1 Conclusions of the Study

Based on the feasibility assessment, it is considered that all proposed options are feasible subject to funding, except for Option B6. Option B6 (2m sediment removal) is not considered feasible, as the creek is typically less than 1m below the overbank (floodplain) area, therefore 2m depth of floodplain excavation would result in a reduced creek profile, significant imbalance in the fluvial regime, as well as ponding. Such work would also make revegetation of the ‘floodplain’ unlikely.

Those options within the road corridor would require approval and possibly implementation by RMS. For these options, the primary consideration is in-ground services and traffic management / road closures.

Options outside the road corridor (i.e. floodplain sediment excavation) present significant constructability constraints and particularly issues with environmental impacts. This is particularly relevant for options at The Bends, where direct disturbance of sensitive and valuable habitat would occur.

Options outside the road corridor (i.e. floodplain sediment excavation) could be implemented by Council with only approvals from RMS being required for temporary road closures / temporary changed traffic conditions. Other environmental approvals would be required.

Regarding staging, options outside the road corridor at The Bends (sediment excavation) are able to be implemented prior to other options within the road corridor and are not necessarily inter-dependant. Therefore, the sediment excavation option at the Bends could be implemented initially, with other options being implemented at a later date.

Residual risks for option implementation include:

- The impact of localised pluvial flooding (ponding) remains a risk for options comprising levee construction or raising.
- further ongoing sediment infill and choking of the creek corridor could continue for options not including sediment removal. Further sedimentation could exacerbate the existing flooding issue.
- environmental approvals and the need for further assessment is required, primarily for sediment removal and road culvert options (at The Bends).
- RMS approvals regarding traffic management (for options outside the road corridor) or road closures and occupancy (for options within the road corridor) would be required. It is understood that limited consultation with RMS has taken place to date.
- the sediment contamination testing undertaken to inform this assessment was limited. To fully classify the sediment prior to removal would require significant additional testing. Should additional testing change the waste classification, then estimated disposal costs would increase significantly, and likely render the option unfeasible due to costs.
- The ability for the excavated sediment to be disposed of offsite (in the case of options involving sediment excavation) has been assumed.
- Several uncertainties remain regarding land ownership.
- Options have been tested based on present day conditions, including rainfall, site constraints and baseline environmental conditions. The present study has not taken account of climate change (potential increase in rainfall intensity) or sea level rise.
- A European Heritage Assessment has not been undertaken.

The feasibility assessment has identified several flood mitigation options, generally providing increasing flood immunity with increasing estimated costs. The best performing option(s) provide flood immunity up to 1 EY (1-year ARI) for the whole parkway. Such flood immunity is achieved with the combination of Option B3 (at The Bends) and Option O1 (at Oxford Falls), with estimated costs of $12.1M (excl. GST) and $1.2M (excl. GST) respectively ($13.3M in total).

Option B4 provides flood immunity up to 0.5 EY (2 year ARI) flood immunity at the Bends at an estimated cost of $13.8M (excl. GST), however the flood immunity of the whole parkway is not realised as it is limited by the Oxford Falls and Sports Academy sites.

7.2 Recommendations

Prior to the progression of one or more options, the following are recommended:

- Geotechnical investigation;
- Waste classification;
- Detailed design; and
- Environmental assessment, including biodiversity assessment.

In addition, the other more catchment management-based options should continue to be considered. As mentioned previously, these have not been assessed as part of the study, but could include:

- Stabilisation of fire trails;
- Construction of additional sediment control measures in the urban areas e.g. GPTs;
- Creek restoration to minimise sediment generation; and;
- Improvements to road drainage.

8 References

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APPENDIX A – RHDHV (2018) Flood Options Assessment

PROVIDED UNDER SEPARATE COVER

APPENDIX B – Photo Record

Haskoning Australia PTY Ltd.
Maritime & Aviation

Note / Memo

To: Click to enter "Recipient"
From: Click to enter "Sender"
Date: 05 April 2019
Copy:
Our reference: PA1943
Classification: Click to enter "Classification Text"

Subject: **Photgraphic Record**

Aerial Images

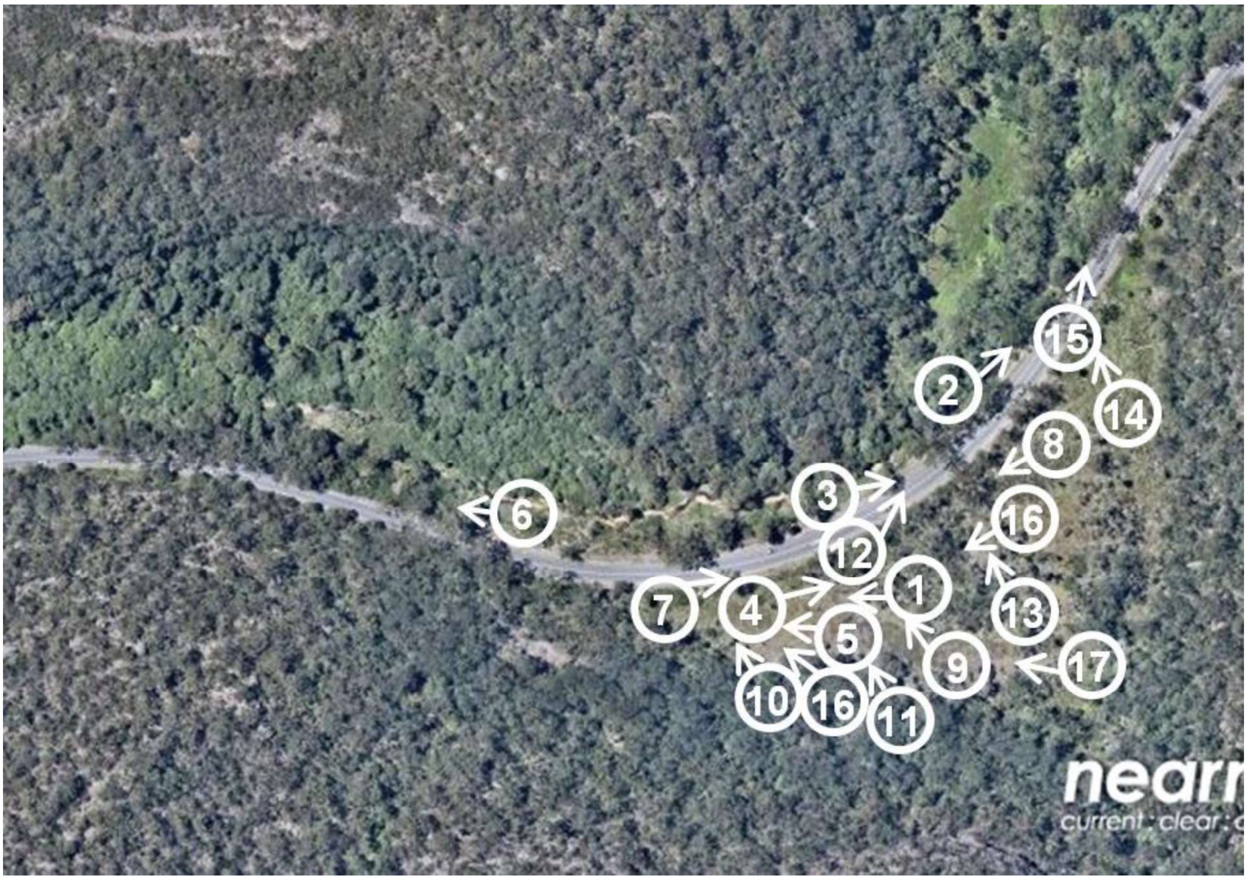


Figure 1: Location of Aerial Images from Appendix A (Nearmap, 2017)


Aerial Image #1


Aerial Image #2

Aerial Image #3

Aerial Image #4

Aerial Image #5

Aerial Image #6

Aerial Image #7

Aerial Image #8

Aerial Image #9

Aerial Image #10

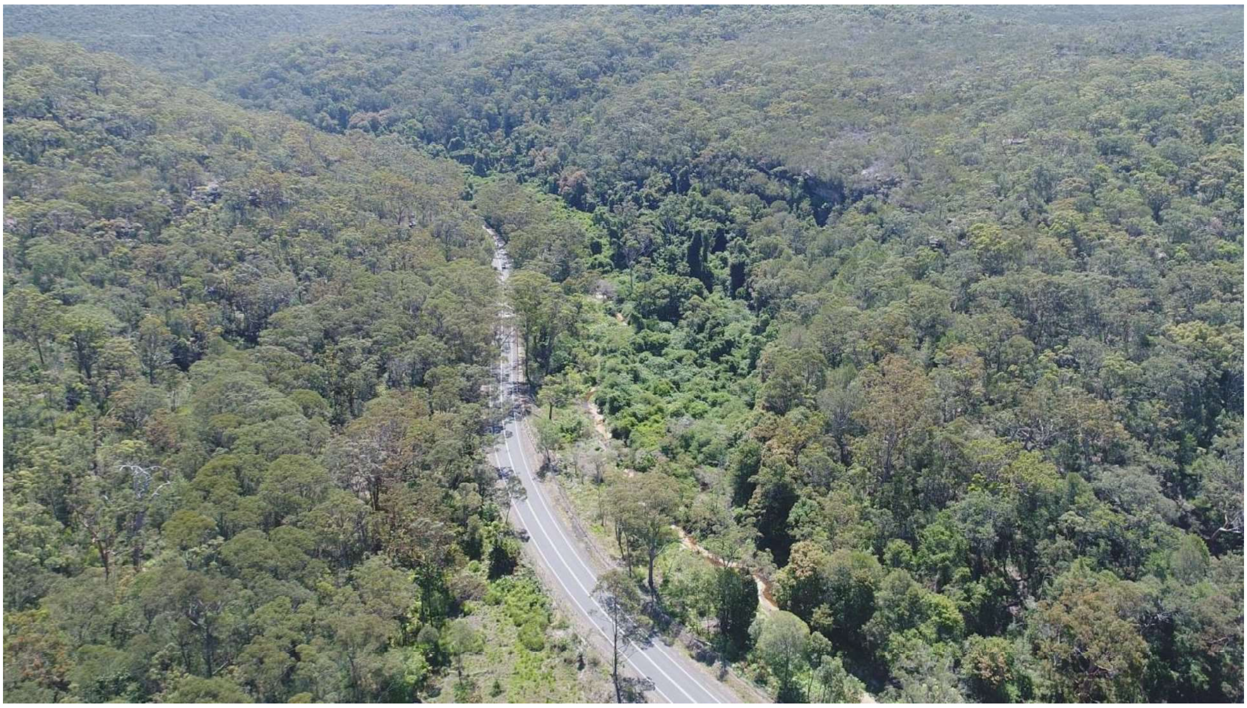
Aerial Image #11

Aerial Image #12

Aerial Image #13

Aerial Image #14

Aerial Image #15



Aerial Image #16

Aerial Image #17

Site Photos (16.11.18 and 21.11.19)

Location of Site Images (Nearmap, 2017)

Site Photo at Location #1 (16.11.18)

Site Photo at Location #1 (16.11.18)

Figure 2: Site Photo at Location #1 (16.11.18)

Figure 3: Site Photo at Location #1 (16.11.18)

Figure 4: Site Photo at Location #1 (16.11.18)

Figure 5: Site Photo at Location #2 (16.11.18)

Site Photo at Location #2 (16.11.18)

Site Photo at Location #2 (16.11.18)

Site Photo at Location #3 (16.11.18)

Site Photo at Location #3 (16.11.18)

Site Photo at Location #3 (16.11.18)

Site Photo at Location #4 (16.11.18)

Site Photo at Location #4 (16.11.18)

Site Photo at Location #5 (21.11.18)

Figure 6: Site Photo at Location #5 (21.11.18)

Figure 7: Site Photo at Location #5 (21.11.18)

Figure 8: Site Photo at Location #5 (21.11.18)

Figure 9: Site Photo at Location #5 (21.11.18)

Figure 10: Site Photo at Location #5 (21.11.18)

Figure 11: Site Photo at Location #5 (21.11.18)

Figure 12: Site Photo at Location #5 (21.11.18)

Figure 13: Site Photo at Location #5 (21.11.18)

Figure 14: Site Photo at Location #5 (21.11.18)

Figure 15: Site Photo at Location #5 (21.11.18)


Figure 16: Site Photo at Location #6 (21.11.18)

Site Photos (28.11.18)

Figure 17: Site Photo at Location # (28-11-18)

Figure 18: Site Photo at Location # (28-11-18)

Figure 19: Site Photo at Location # (28-11-18)

Figure 20: Site Photo at Location # (28-11-18)

Figure 21: Site Photo at Location # (28-11-18)

Figure 22: Site Photo at Location # (28-11-18)

Figure 23: Site Photo at Location # (28-11-18)

Figure 24: Site Photo at Location # (28-11-18)

Figure 25: Site Photo at Location # (28-11-18)

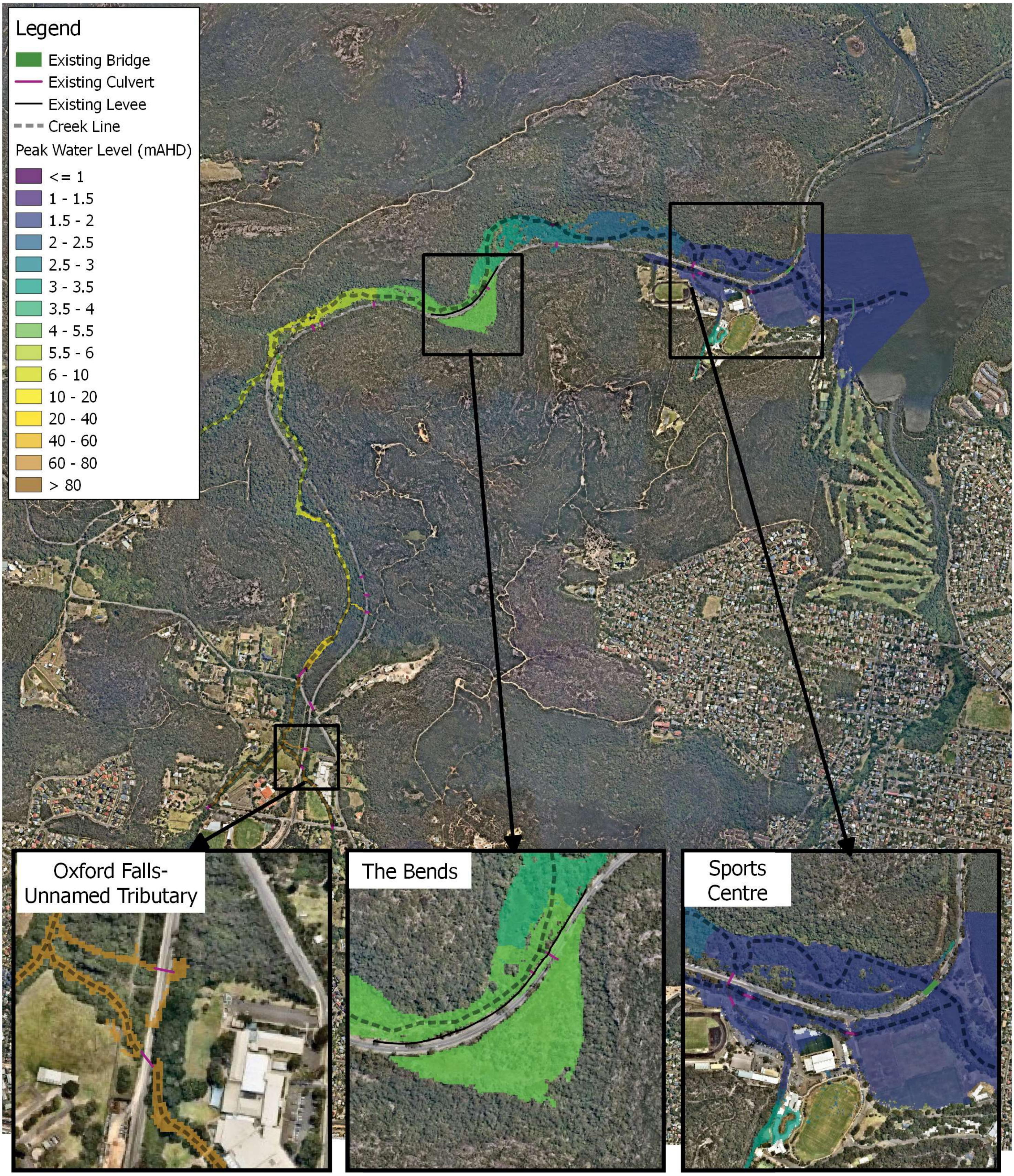
Figure 26: Site Photo at Location # (28-11-18)

Figure 27: Site Photo at Location # (28-11-18)

Figure 28: Site Photo at Location # (28-11-18)

Figure 29: Site Photo at Location # (28-11-18)

APPENDIX C – Existing Flood Mapping



Title: Existing Water Level- 4 EY

Figure: A1

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

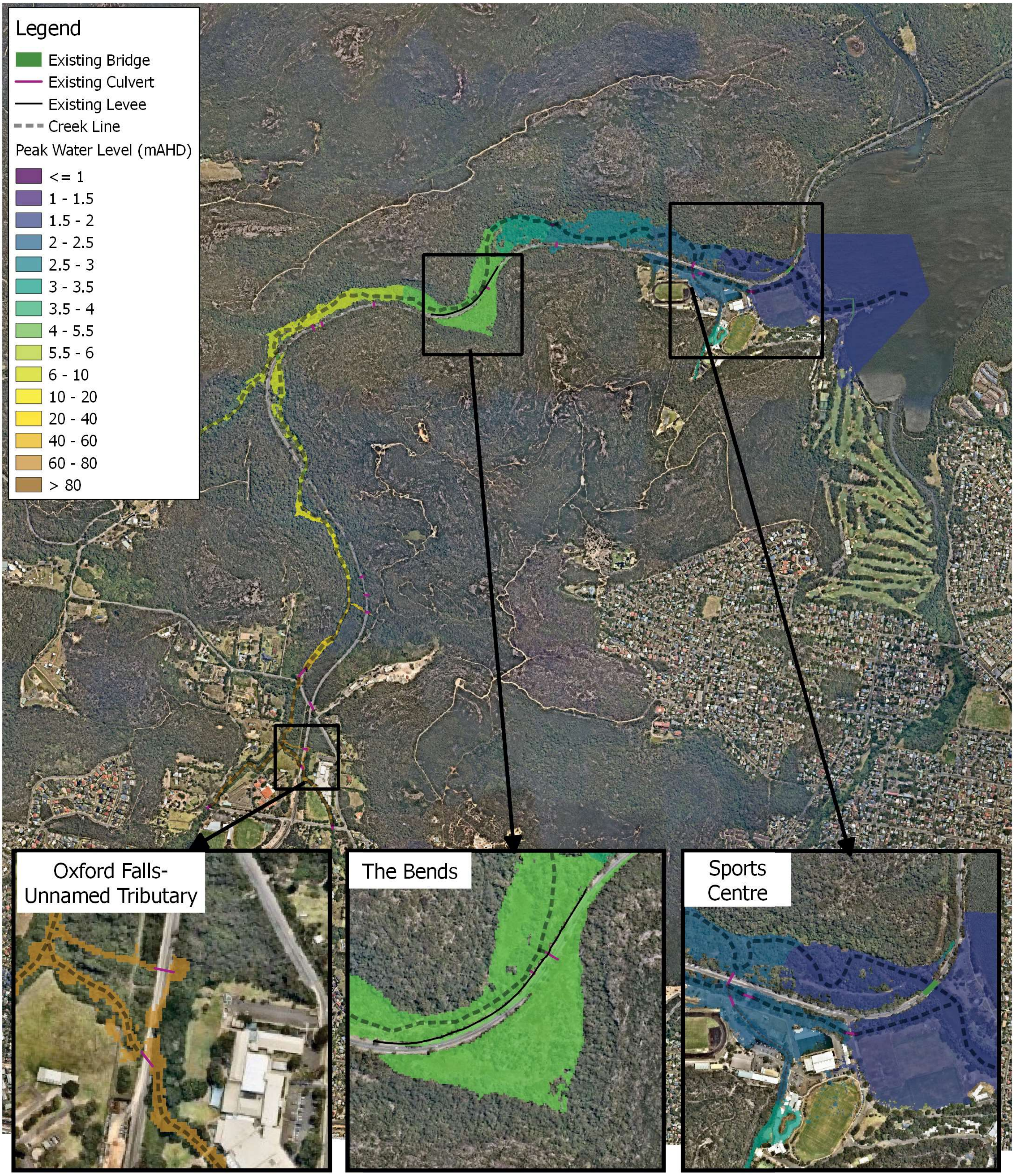
0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

Royal HaskoningDHV
Enhancing Society Together

Created 12/07/2018. KA. \\auntlmspinf001\AU-NewCastle-MarketStreet\PA1149\Technical_Data\PA1149-111_Wakehurst_Parkway\E7_GIS\QGIS\Wakehurst_Master_Mapper.qgs



Title: Existing Water Level- 2 EY

Figure: A2

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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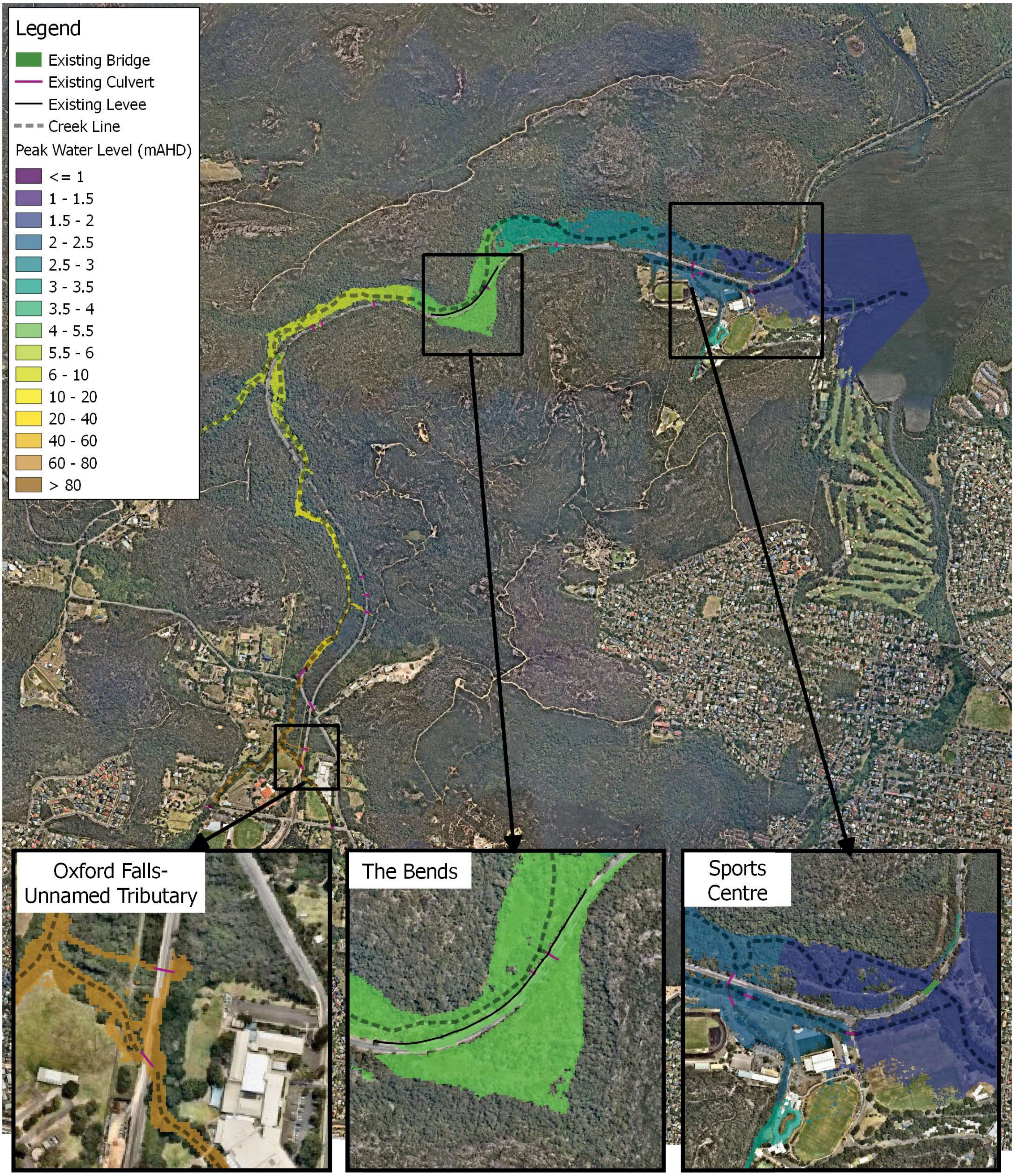

Title: Existing Water Level- 1 EY

Figure:
A3

Rev:
1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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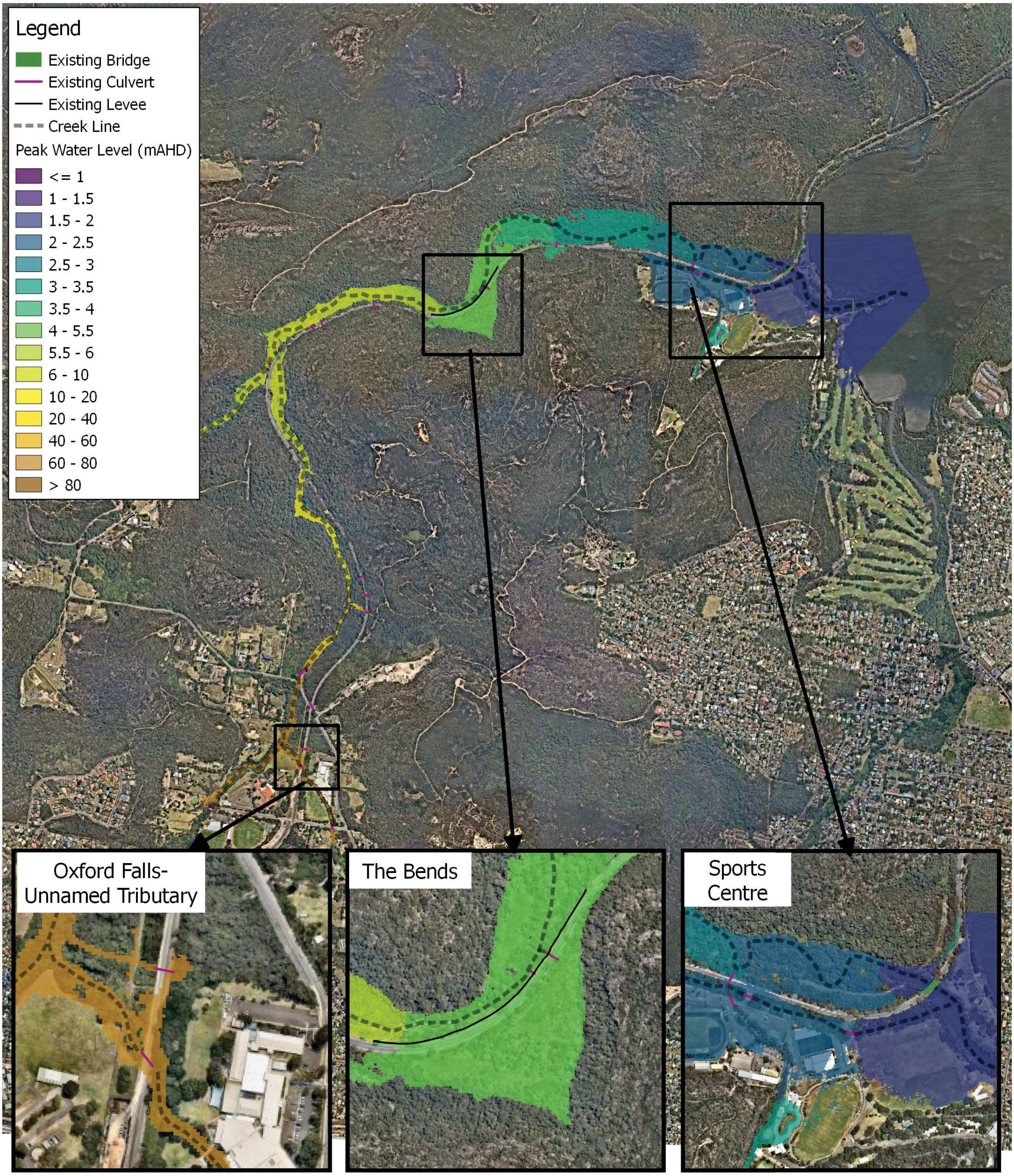
Created 12/07/2018. KA. \\auntlmspinf001\AU-NewCastle-MarketStreet\PA1149\Technical_Data\PA1149-111_Wakehurst_Parkway\E7_GIS\QGIS\Wakehurst_Master_Mapper.qgs



Title: Existing Water Level- 0.5 EY

Figure:
A4

Rev:
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Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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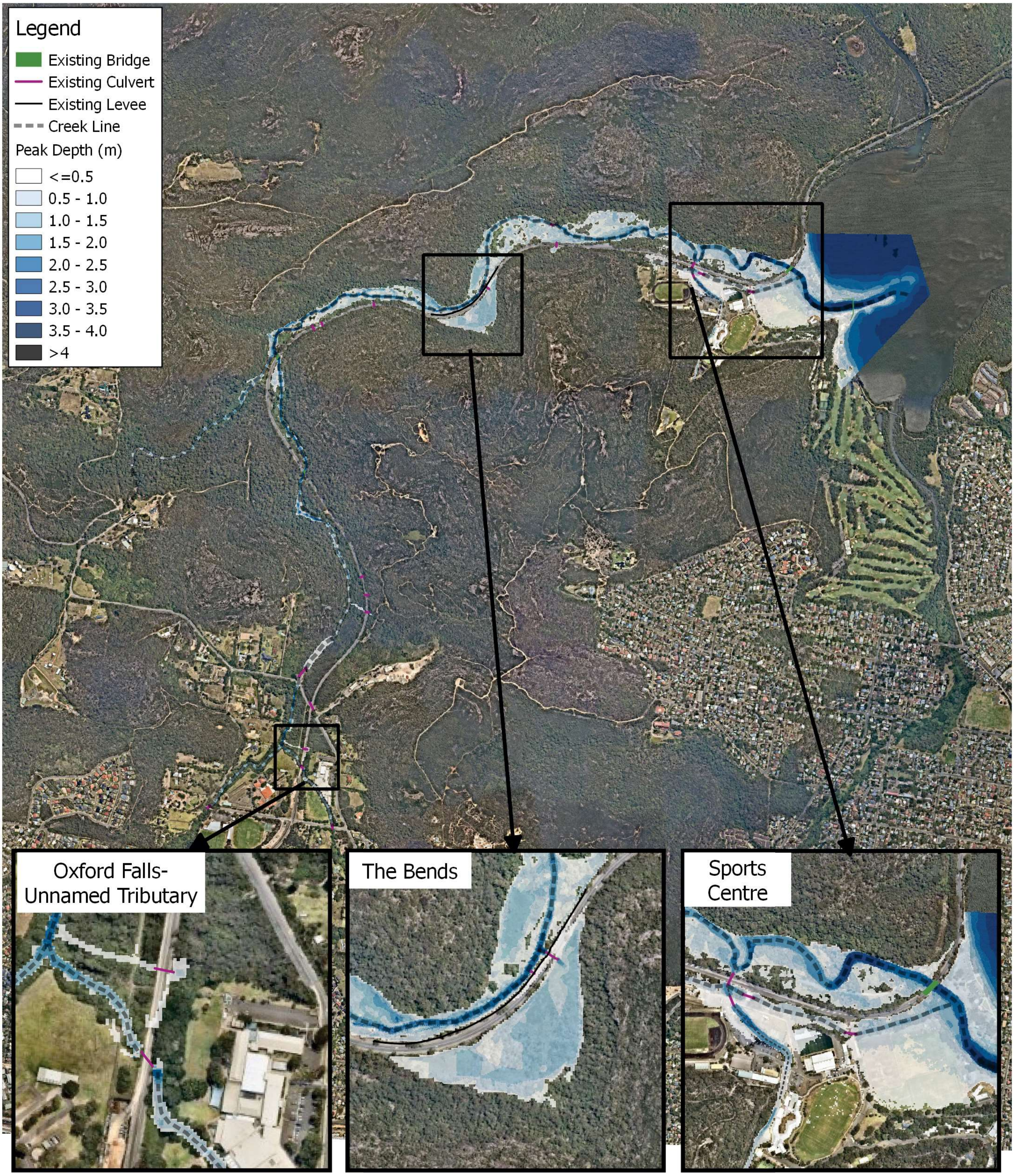

Title: Existing Depth- 4 EY

Project: Wakehurst Parkway- Options Analysis

Figure: A5

Rev: 1

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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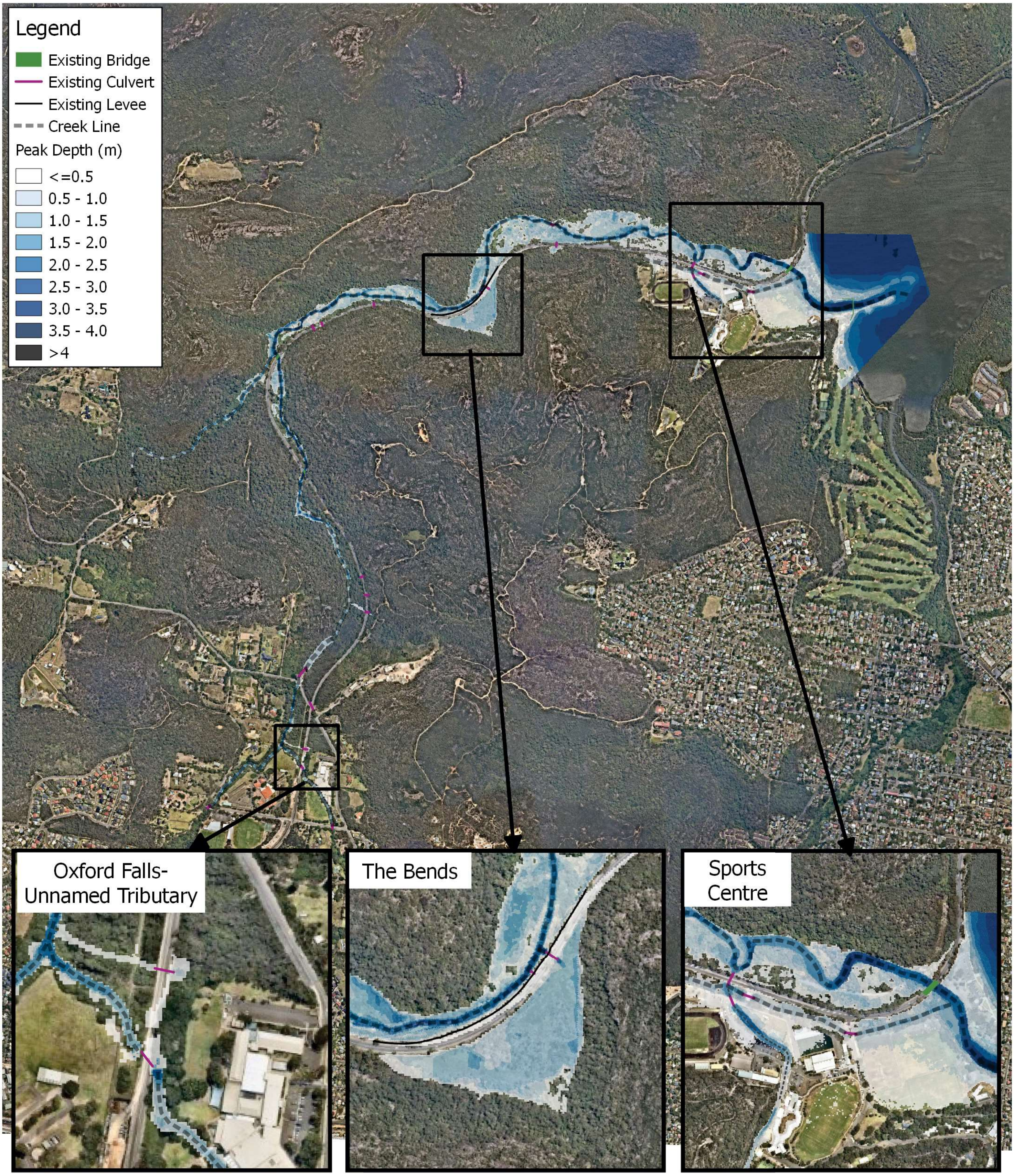

Title: Existing Depth- 2 EY

Figure:
A6

Rev:
1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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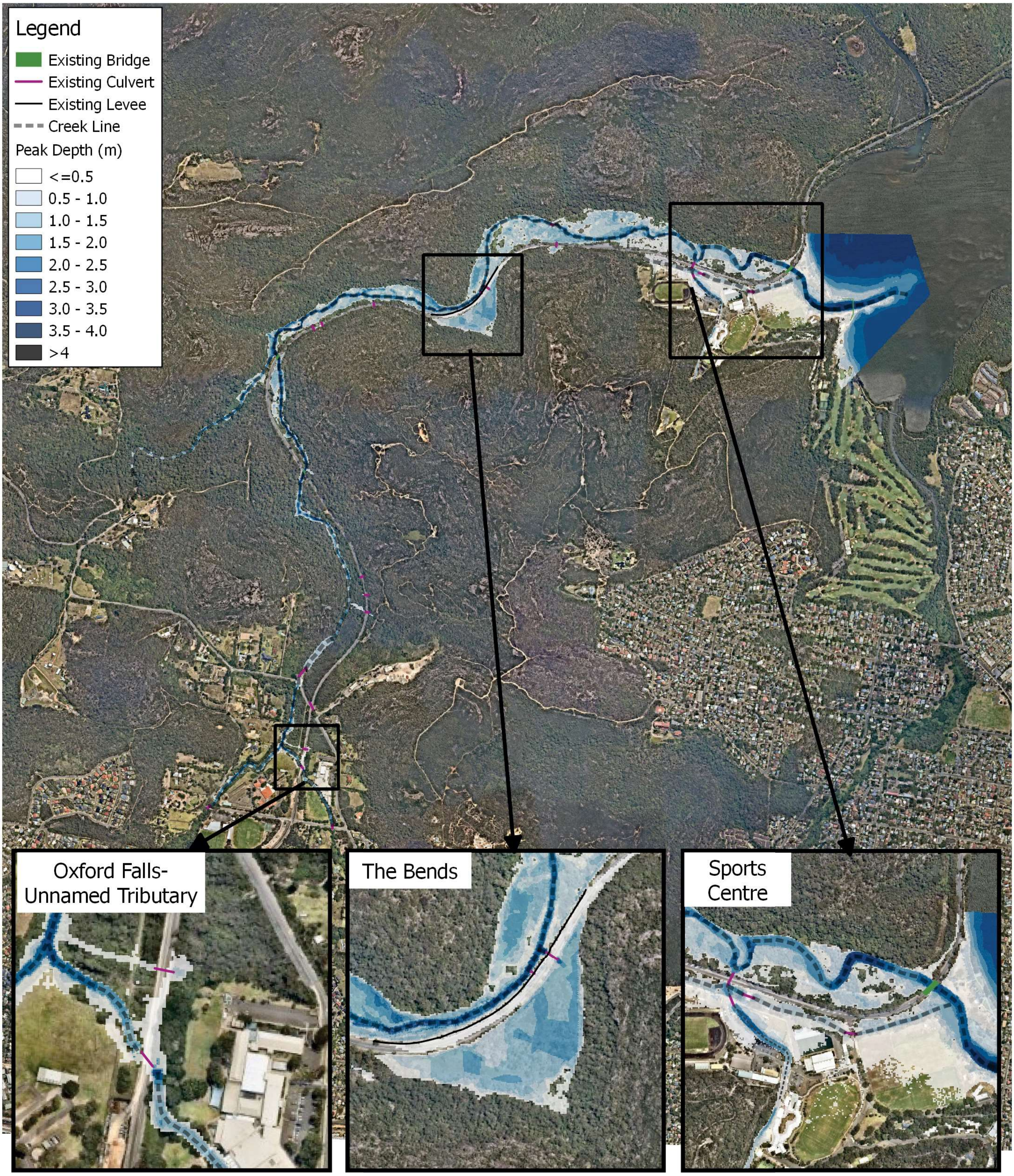

Title: Existing Depth- 1 EY

Project: Wakehurst Parkway- Options Analysis

Figure: A7

Rev: 1

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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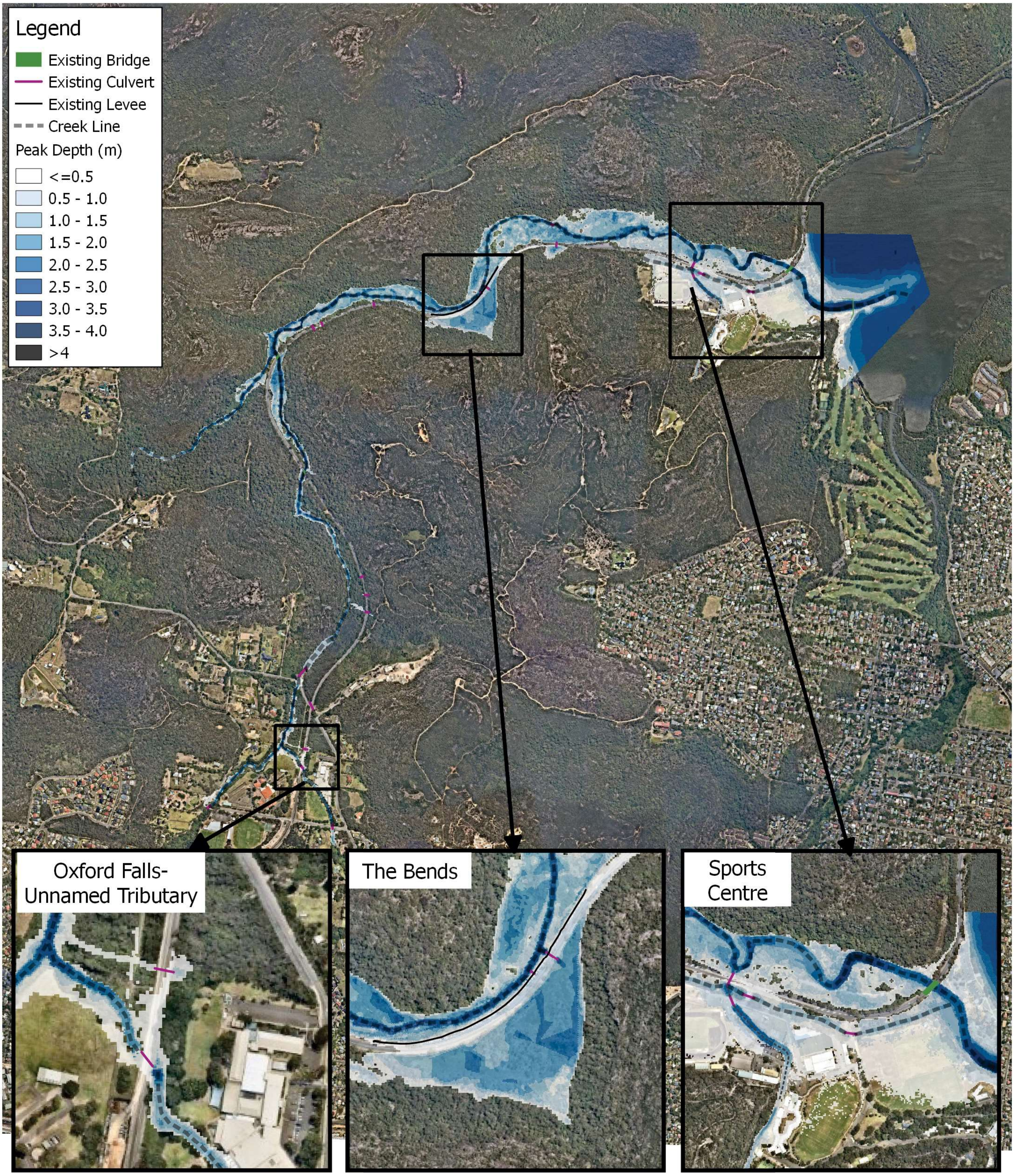

Title: Existing Depth- 0.5 EY

Project: Wakehurst Parkway- Options Analysis

Figure: A8

Rev: 1

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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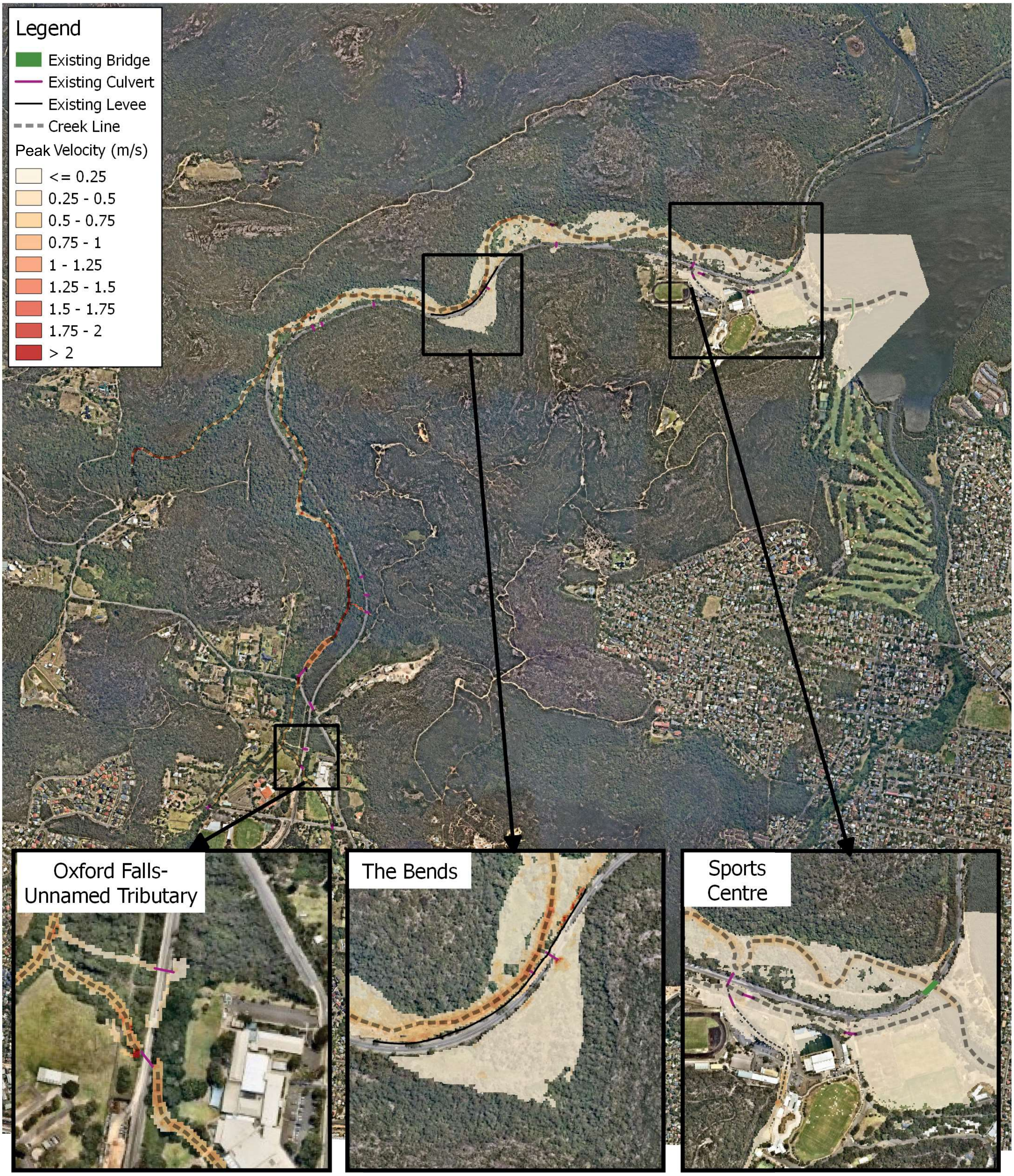

Title: Existing Depth- 4 EY

Figure: A9

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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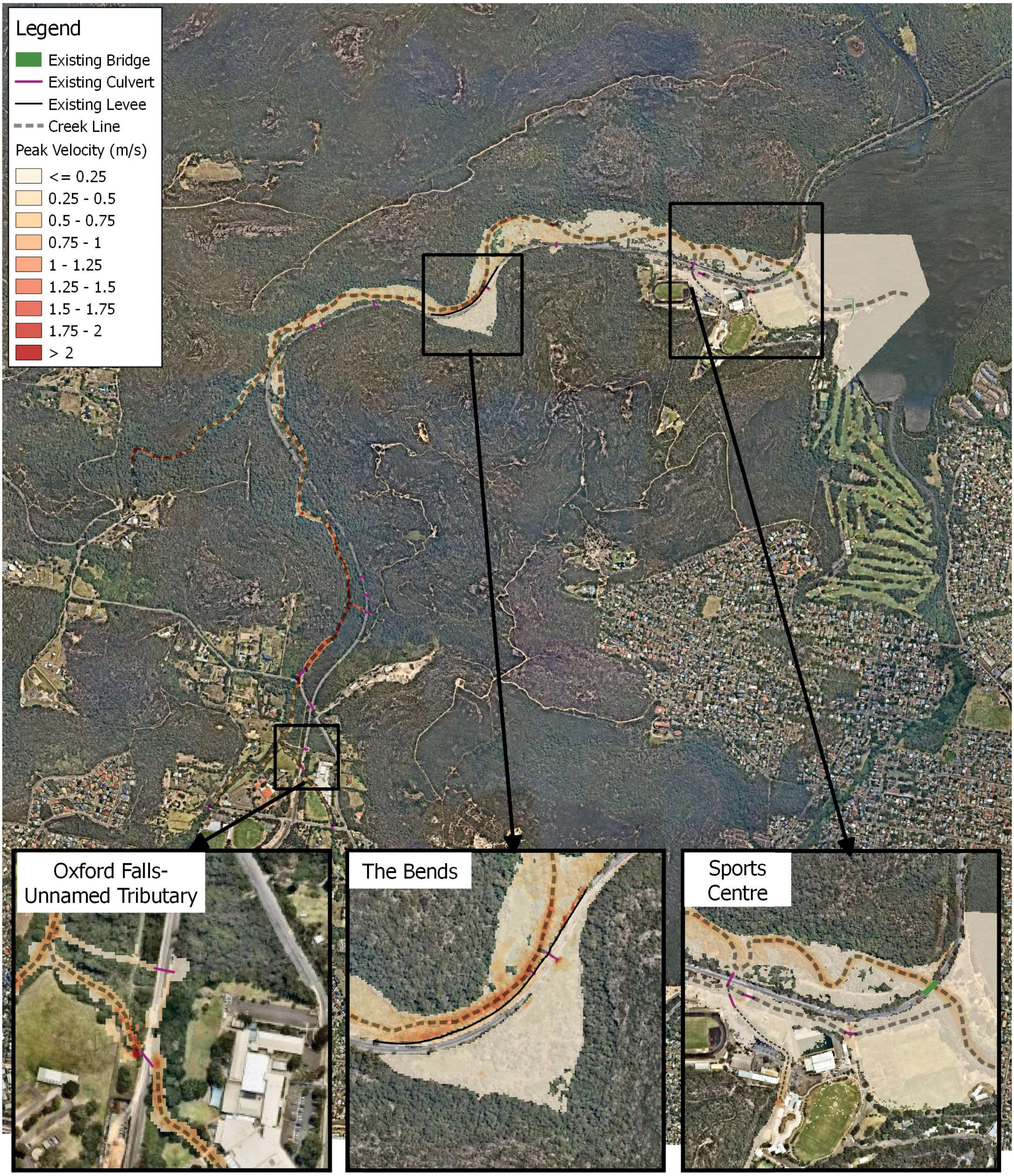

Title: Existing Depth- 2 EY

Project: Wakehurst Parkway- Options Analysis

Figure: A10

Rev: 1

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_EXG_011

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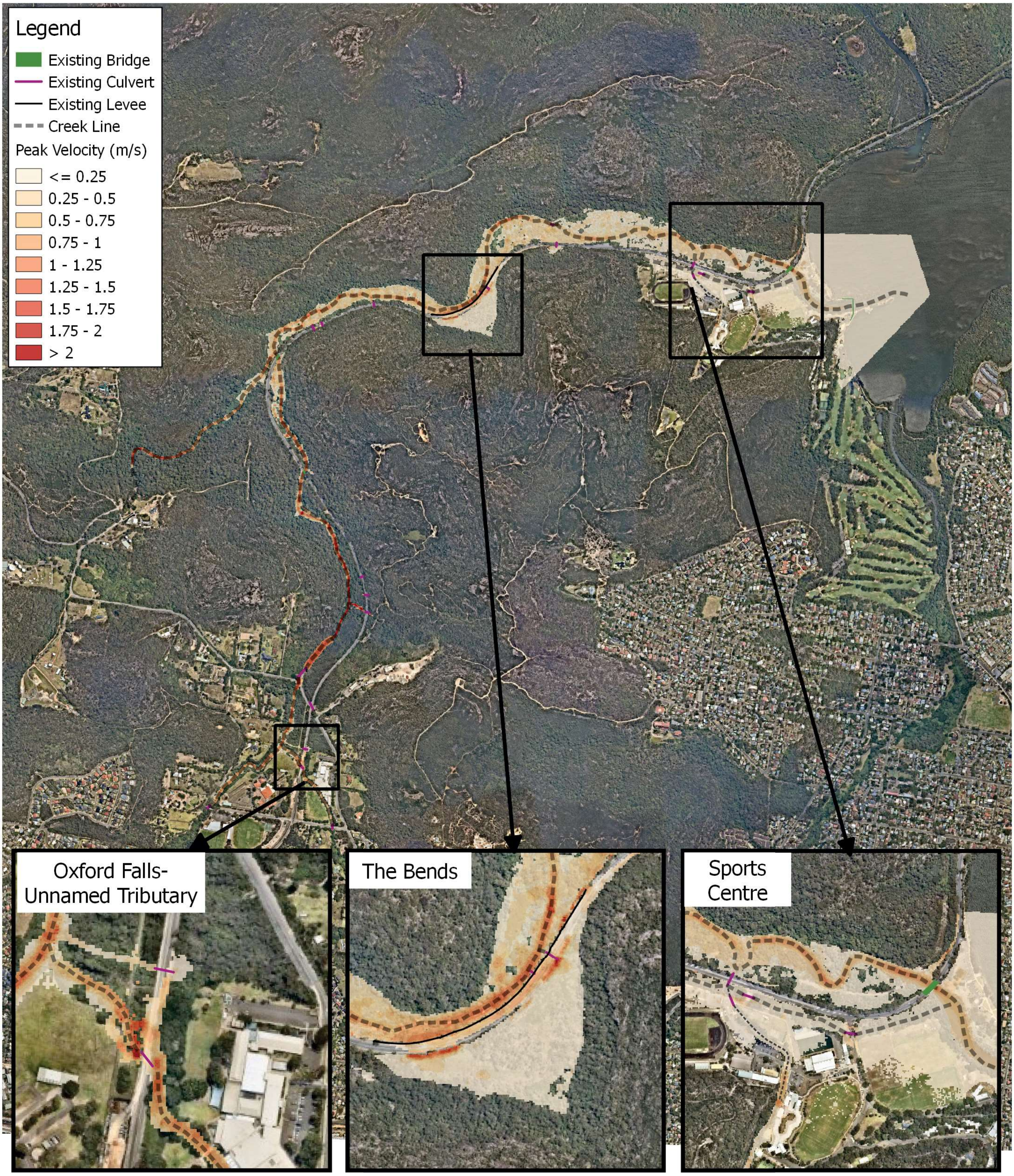

Title: Existing Depth- 1 EY

Project: Wakehurst Parkway- Options Analysis

Figure:
A11

Rev:
1

N

0 200 400 600 800 1000 m

Main Map Only

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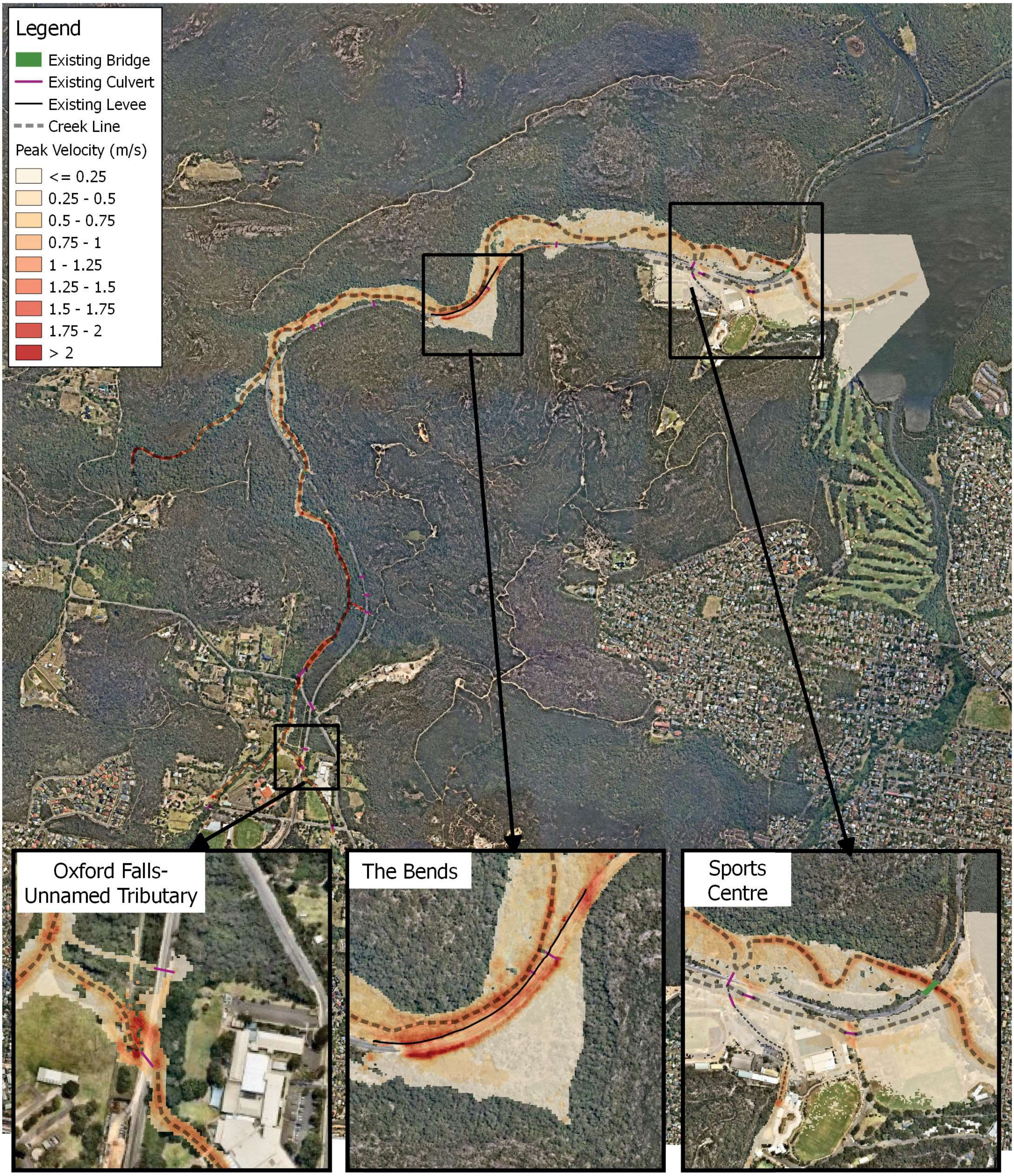

Title: Existing Depth- 0.5 EY

Figure: A12

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

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TUFLOW ID: WP_()_GPU_EXG_011

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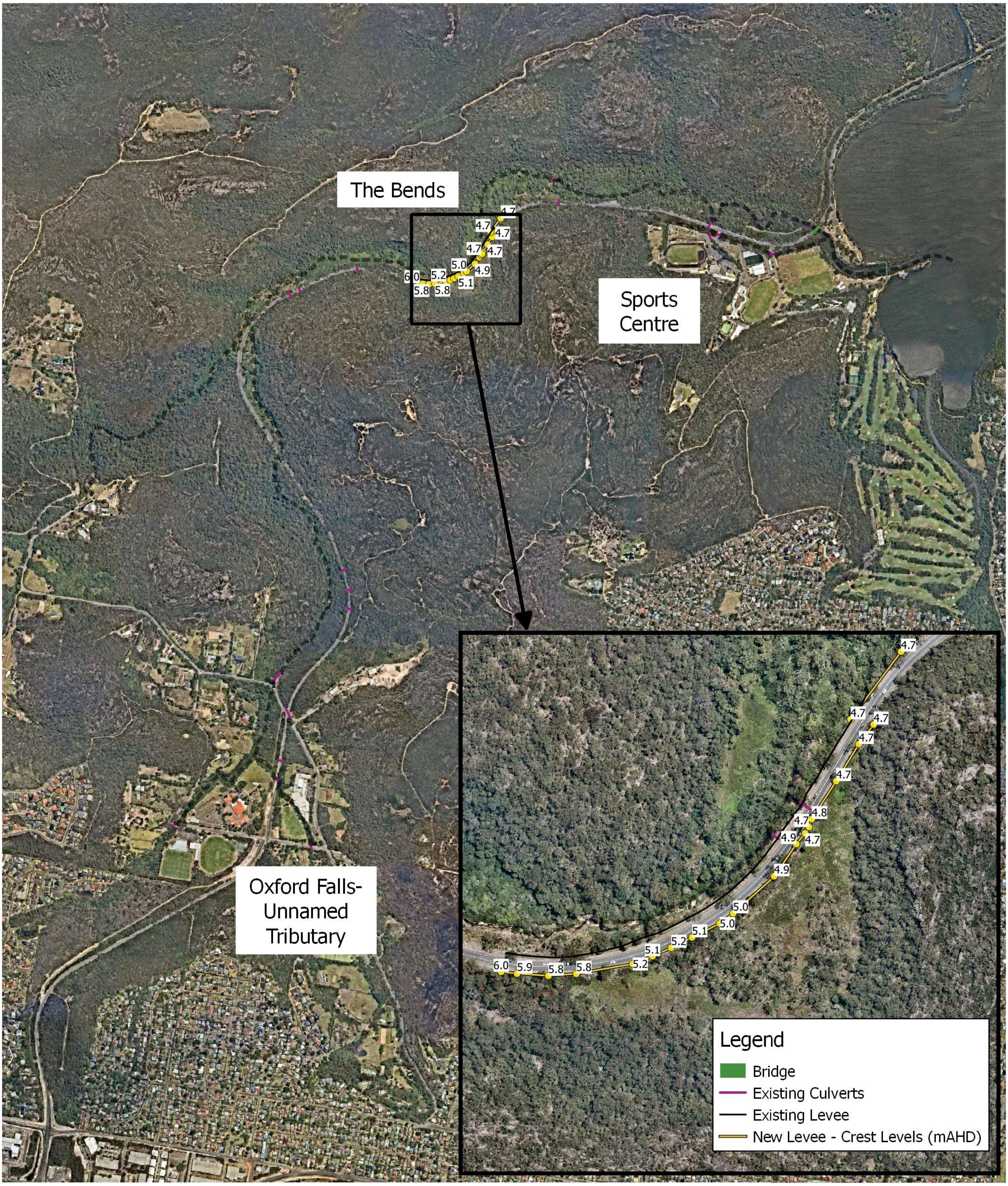

Title: Option B1- New Levee

Figure: F1

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_Po1_010

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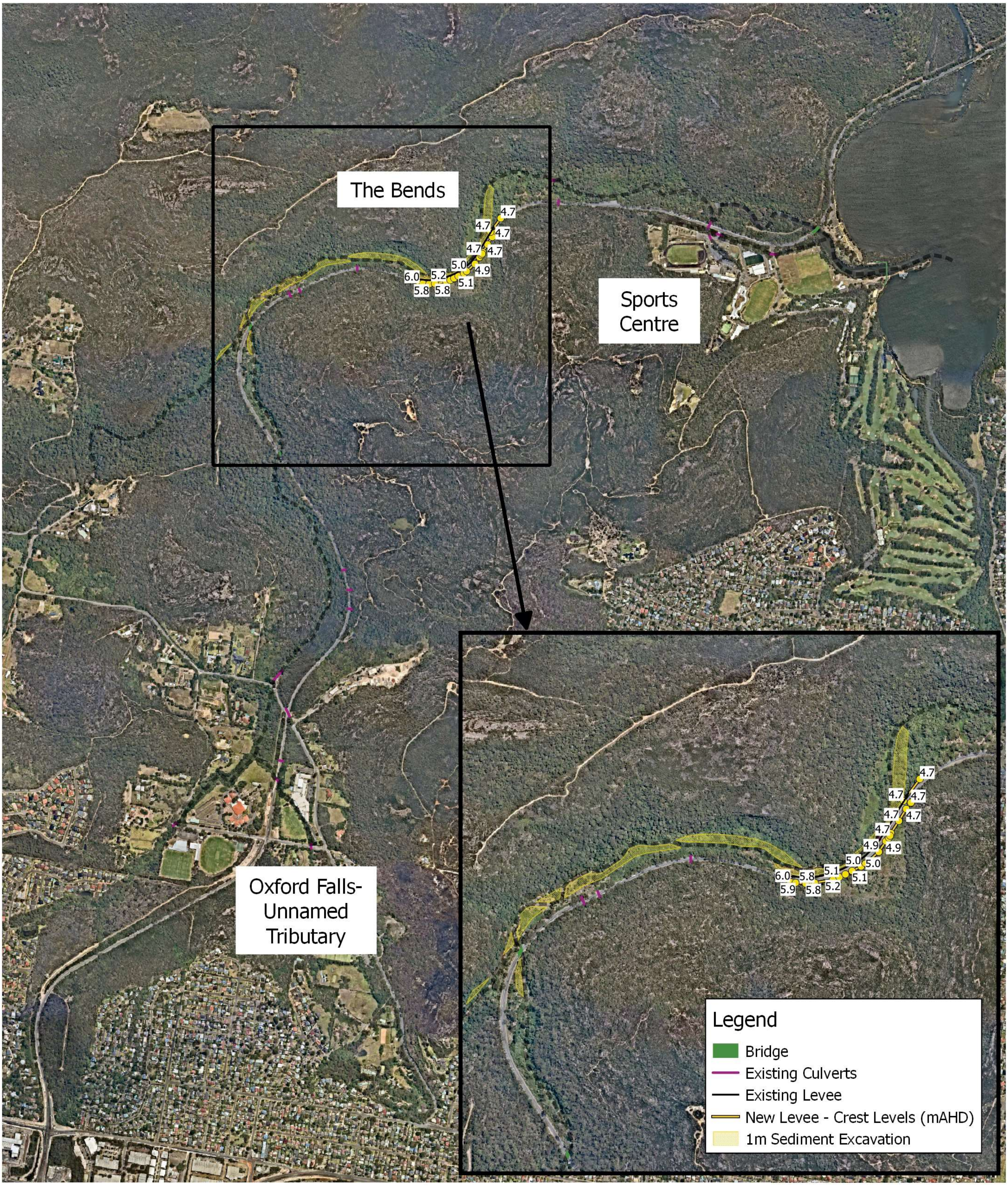

Title: Option B2 - New Levee and Removal of Overbank Sediment

Figure: F2

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_Po2_010

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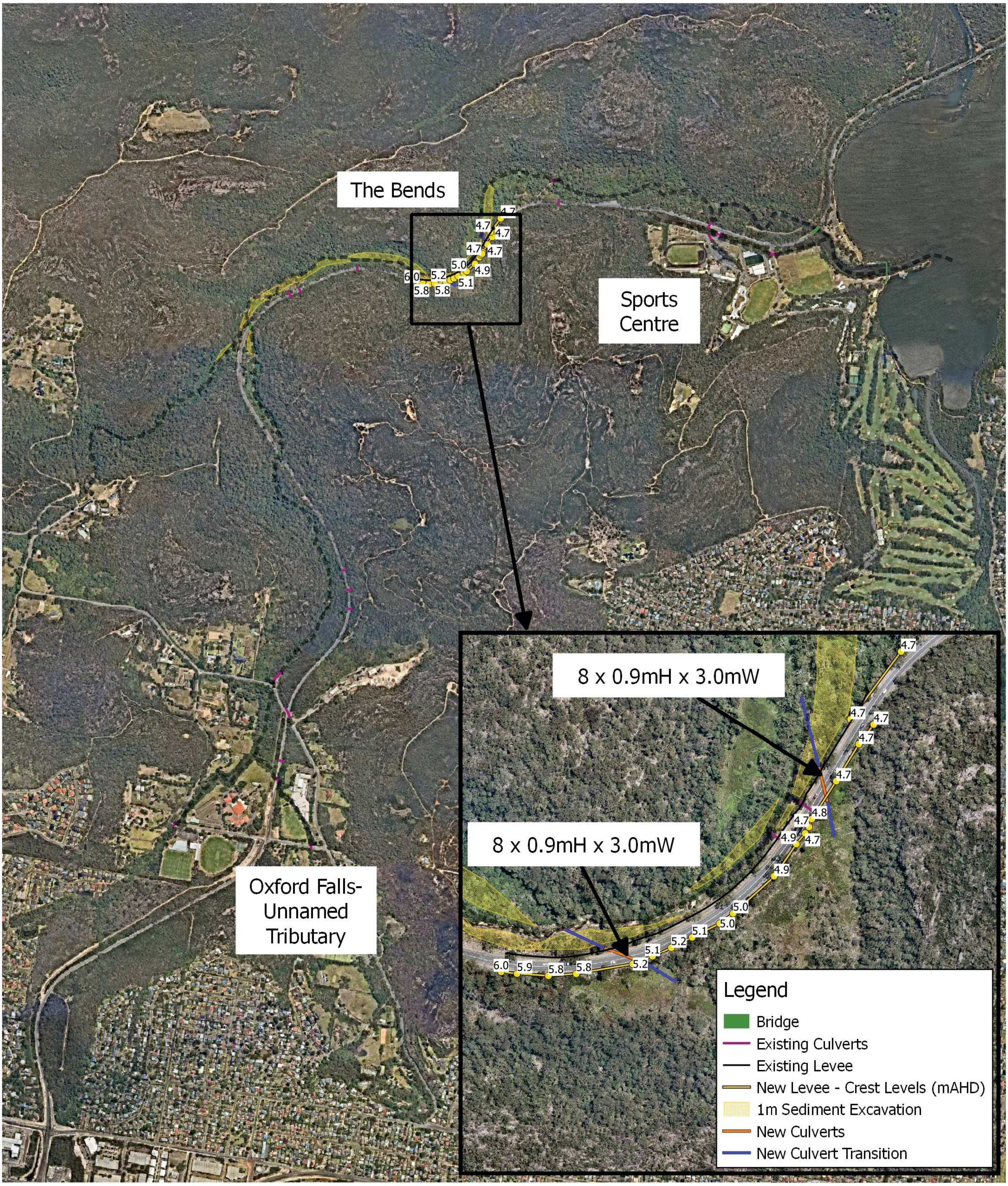

Title: Option B3 - New Levee, Removal of Overbank Sediment & Culverts Under Road

Figure: F3

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_Po3_010

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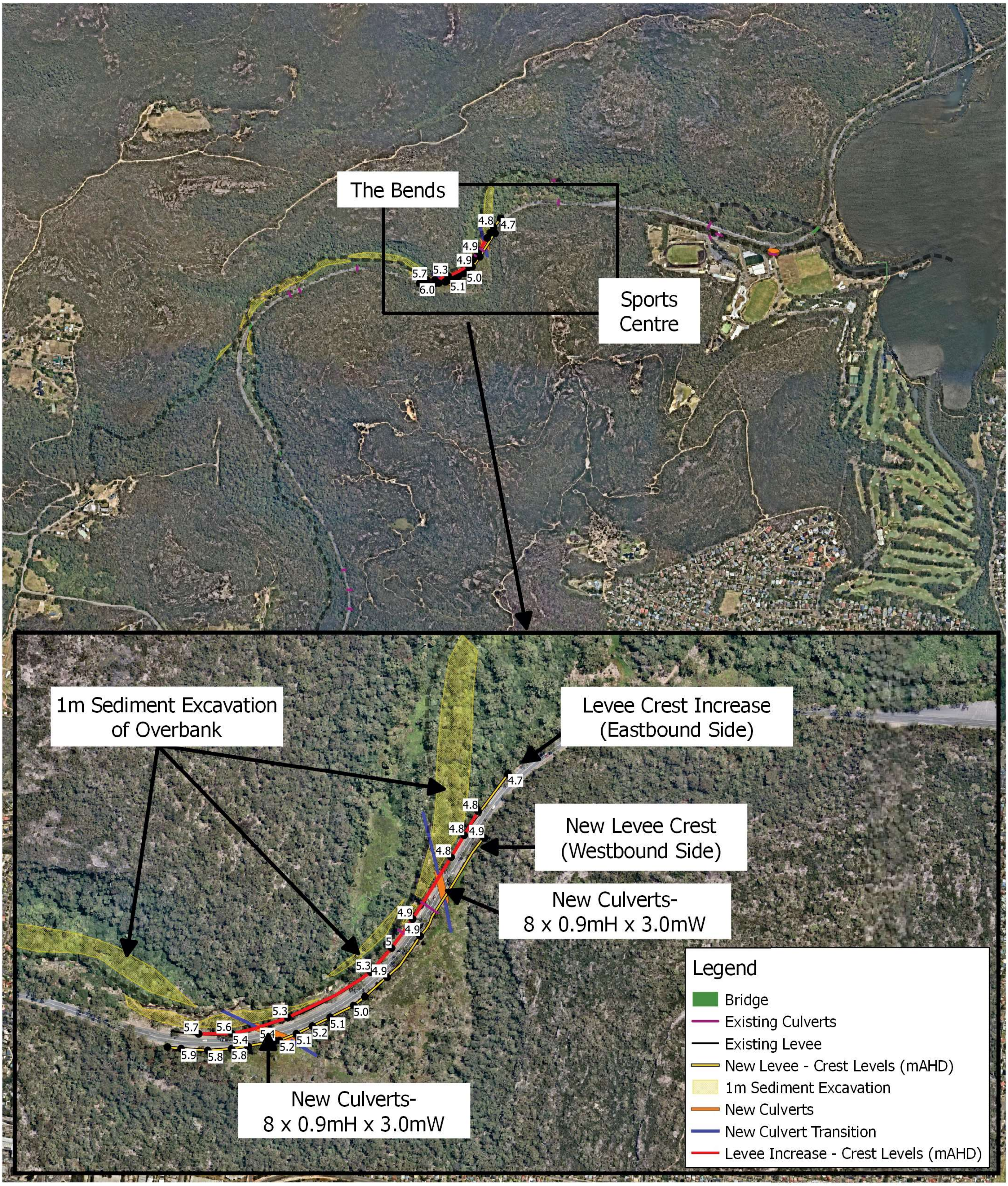

Title: Option B4 - New Levee, Removal of Overbank Sediment, Culverts Under Road & Top-up of Existing Levee

Figure: F4

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_Po7_014

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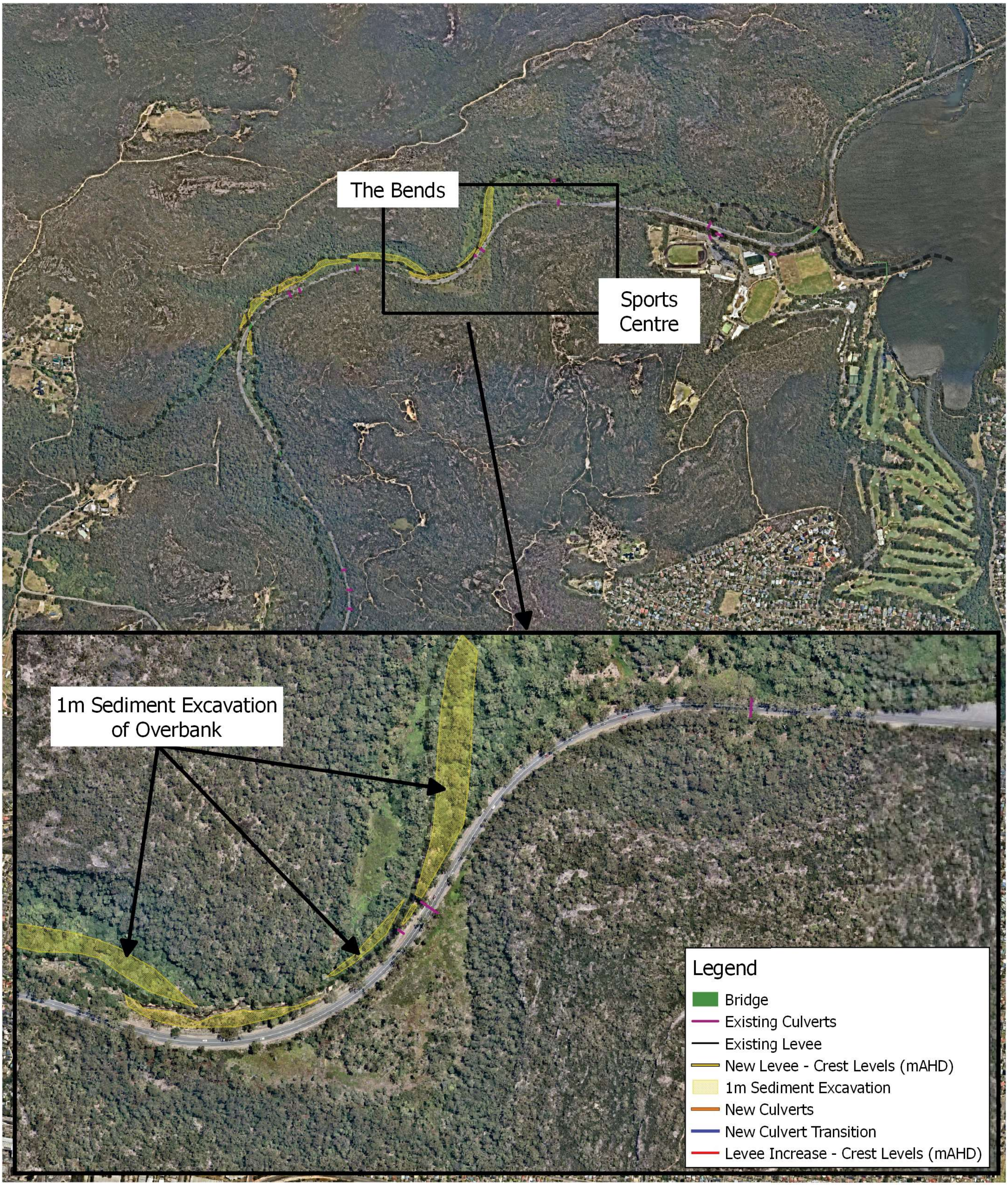

Title: Option B5- Removal of Overbank Sediment (1m)

Figure: F5

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_Po8_014

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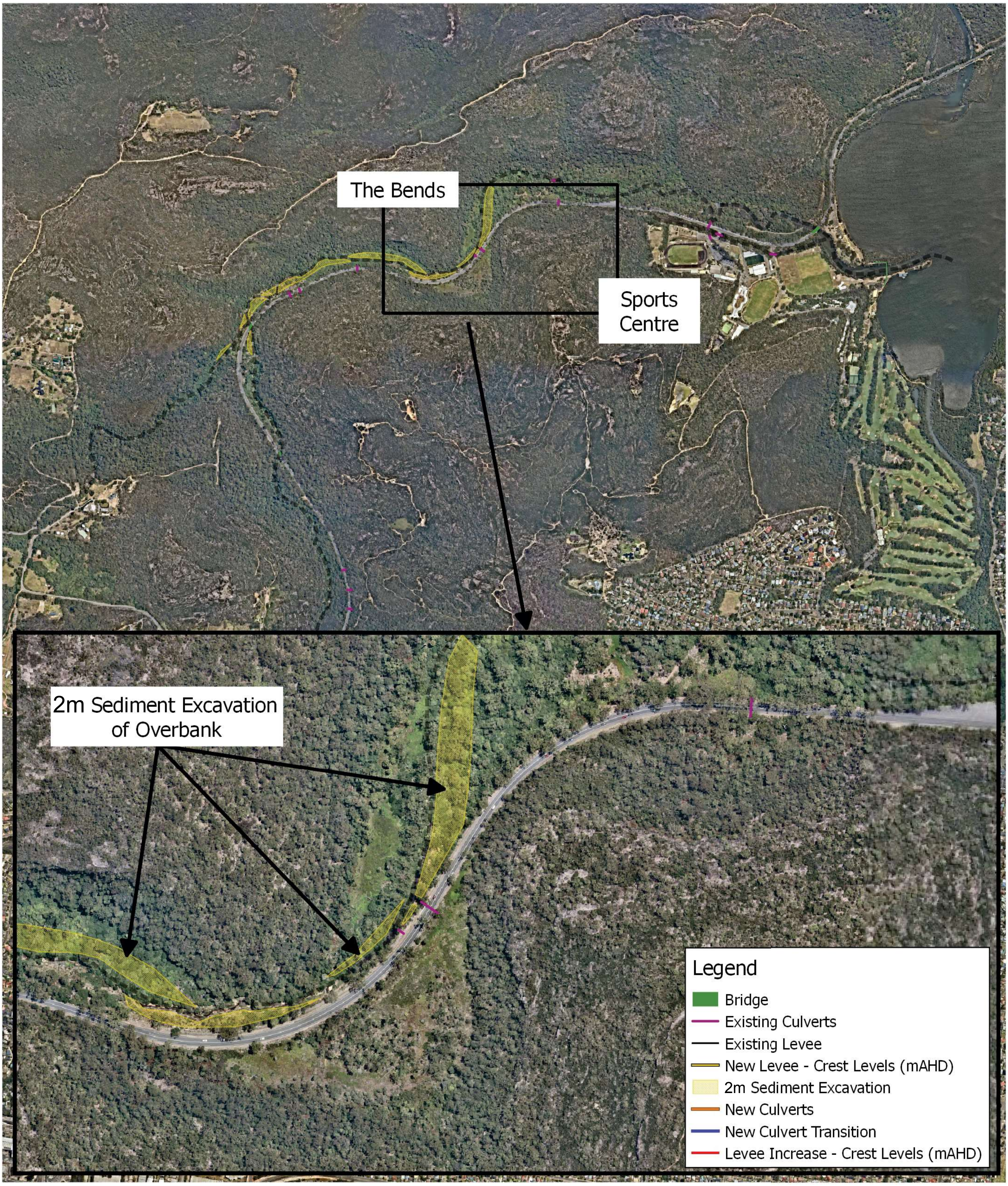

Title: Option B6- Removal of Overbank Sediment (2m)

Figure:
F6

Rev:
1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_Po9_014

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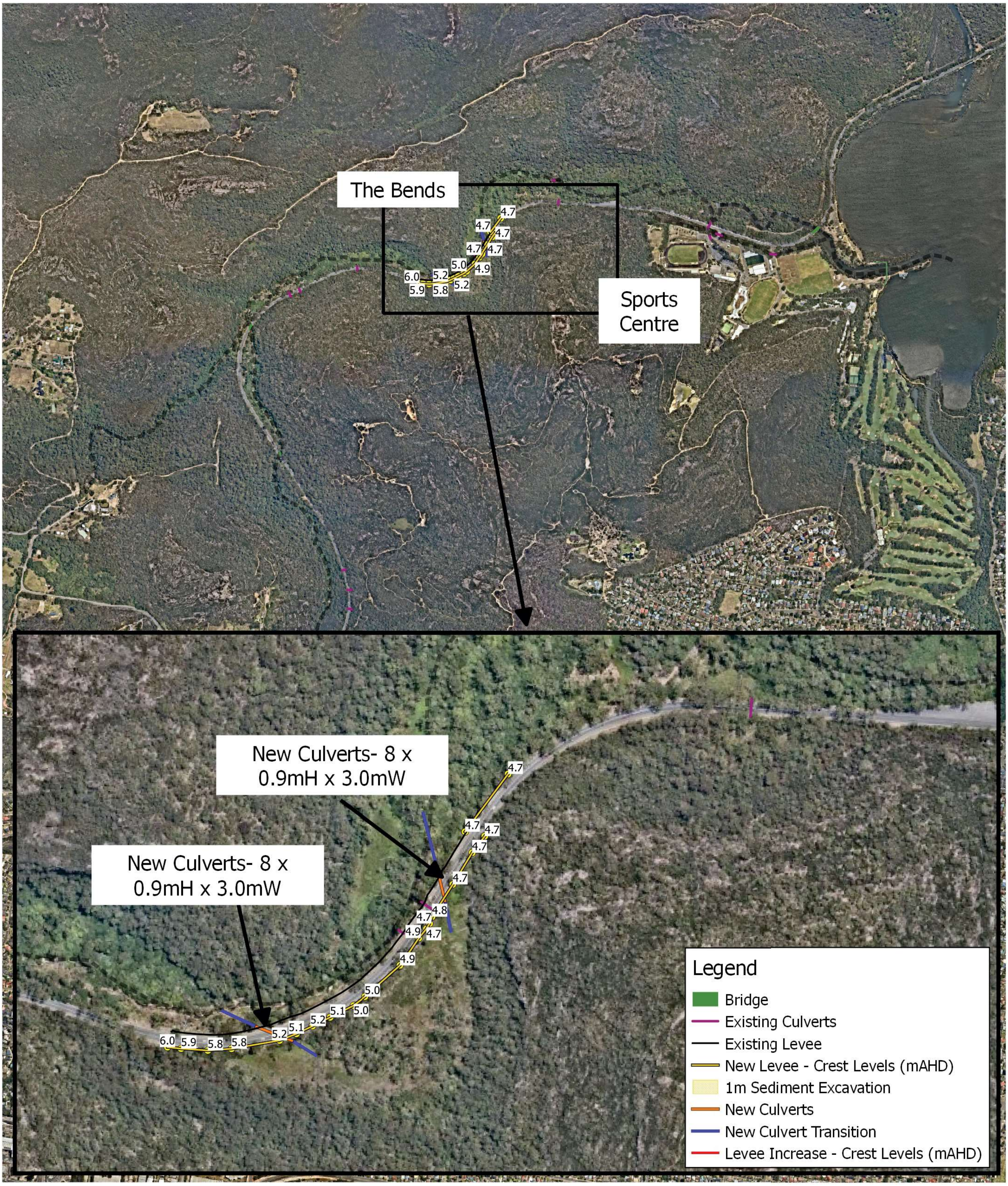

Title: Option B7- New Levee, Under Road Culverts

Figure: F7

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: P15_018

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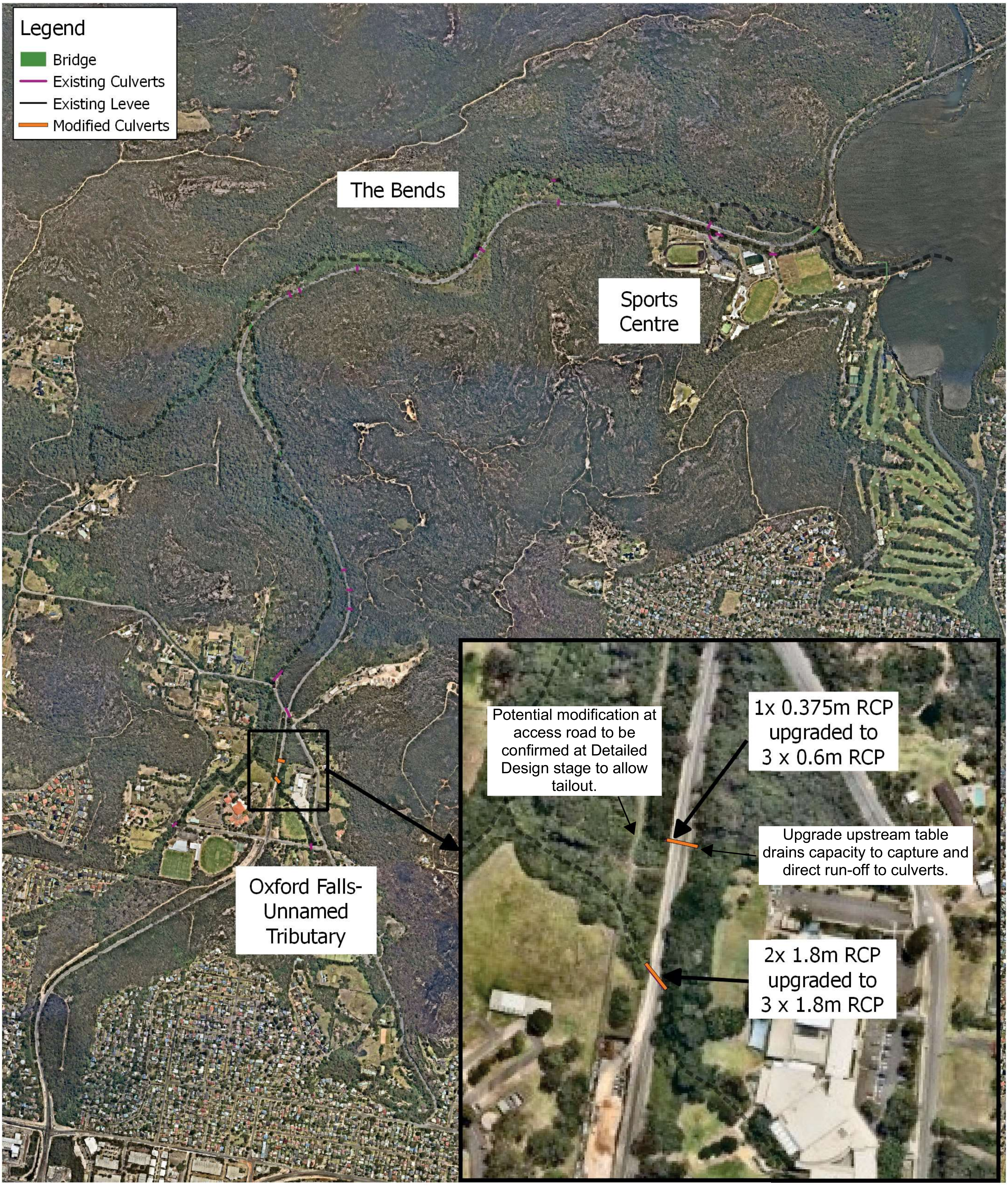

Title: Option O1- Culvert Capacity Increase

Figure: F8

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_Po4_013

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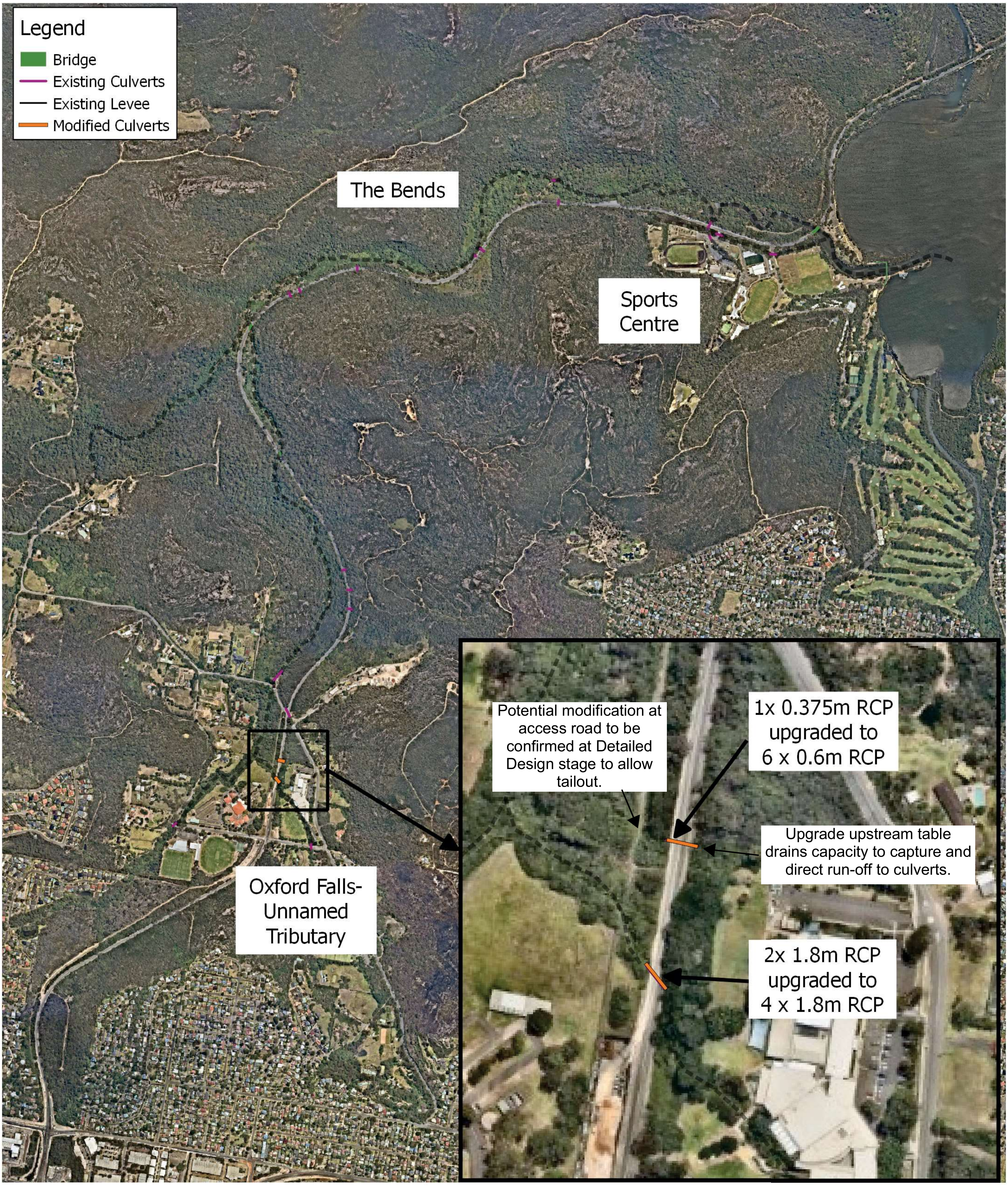

Title: Option O2- Culvert Capacity Increase (2 year immunity)

Figure: F9

Rev: 1

Project: Wakehurst Parkway- Options Analysis

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: WP_()_GPU_P10_015

Royal HaskoningDHV
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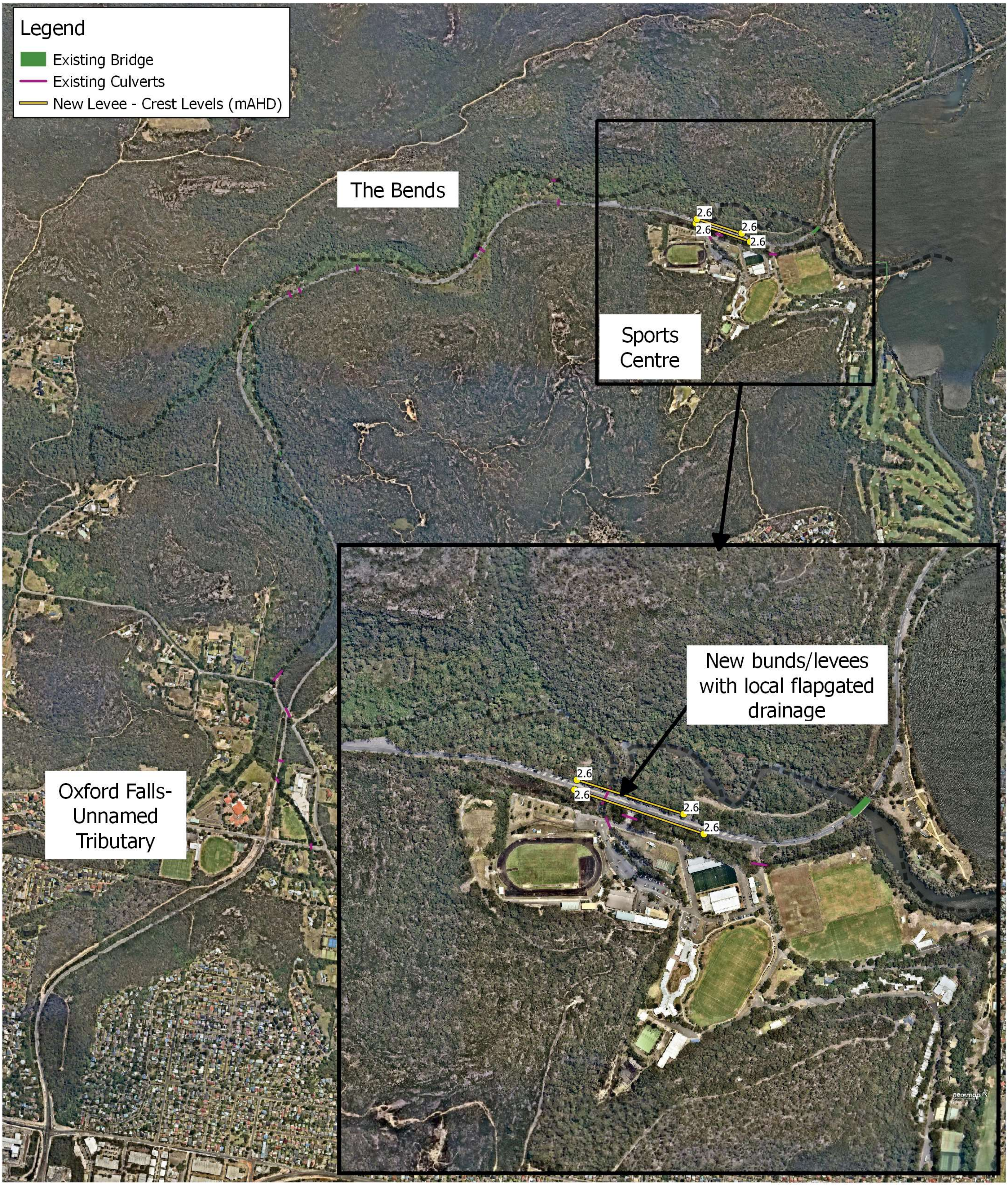

Title: Option S1- Bunds and localised low point drainage

Project: Wakehurst Parkway- Options Analysis

Figure: F10

Rev: 1

N

0 200 400 600 800 1000 m

Main Map Only

TUFLOW ID: P14_018

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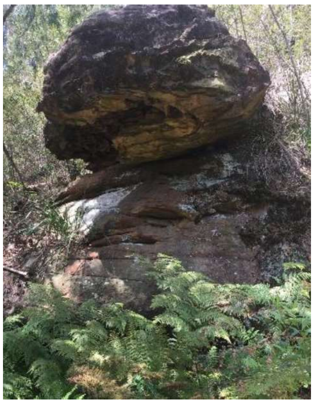
APPENDIX D – Heritage Assessment

Wakehurst Parkway Flood Mitigation

Due Diligence Archaeological Assessment

December 2018



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Document control

Project no.:	190030
Project client:	Northern Beaches Council
Project proponent:	Northern Beaches Council
Document description:	Due Diligence Report
Project Manager:	Nicola Hayes
Authors:	Jasmine Fenyvesi
Internal review:	Nicola Hayes
Document status:	V2
Local Government Area:	Northern Beaches Council - Narrabeen

Document revision status

Author	Revision number	Internal review	Date issued
Jasmine Fenyvesi	1	Nicola Hayes	1/11/18
Nicola Hayes	2		6/12/18

Cover photographs: NOHC October 2018

EXECUTIVE SUMMARY

This report documents the results of a Due Diligence archaeological assessment of the Wakehurst Parkway Flood Mitigation project.

This assessment is undertaken to satisfy the NSW Office of Environment and Heritage *Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales*:

The current project is focused on the 4.5 kilometre stretch of road running alongside Middle Creek, from Oxford Falls to Narrabeen Lagoon, where regular flooding occurs, causing the road to be closed.

Three locations in particular have been identified as problematic areas for over-road flooding:

- The Sports Academy;
- The Bends; and
- Oxford Falls.

As part of works to counteract these flooding occurrences the Northern Beaches Council has proposed a series of flood mitigation options including; sediment removal, culvert upgrades, stream creation/ widening, and the implementation/ upgrade of levees. All of these options would require some level of ground disturbance.

58 Aboriginal site recordings and an Aboriginal place are listed on the OEH AHIMS for the area around the Wakehurst Parkway study area. None are located within the current study area.

Two locally listed historic sites sit in close proximity to the study area. Middle Creek Bridge No. 2 (I151) sits 10 metres away from the sediment removal area at The Bends, and Bridge No. 3 over Middle Creek (I146) sits 25 metres away from the proposed channel at the Sports Academy. There are no plans for the heritage sites to be impacted by the proposal.

Background research and field inspection of the study area did not identify any Aboriginal sites or potential archaeological deposits (PADs) in the study area. The area has been disturbed since European exploration of the area. The construction of Wakehurst Parkway and sediment build-up have had a massive impact on the area in particular.

It is recommended that:

1. No further archaeological assessment is required for the Wakehurst Parkway Flood Mitigation project.
2. The unanticipated discovery protocols included in Appendix 2 should be put in place for the project.
3. A copy of this report should be provided to the Metro Local Aboriginal Land Council.

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Figures

1 INTRODUCTION

1.1 Project Framework

This assessment is undertaken to satisfy the NSW Office of Environment and Heritage *Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales*.

This Code of Practice helps individuals and organisations to exercise due diligence when conducting activities that may harm Aboriginal objects and to identify whether they need to apply for an Aboriginal Heritage Impact Permit (AHIP) (NSW DECCW 2010: 2).

The Code sets out the steps to take in order to:

1. identify whether or not Aboriginal objects are, or likely to be, present in an area;
2. determine whether or not their activities are likely to harm Aboriginal objects (if present); and
3. determine whether an AHIP application is required.

The steps are (Figure 1.1):

Step 1: Determine if the activity will disturb the ground surface.

Step 2a: Search the AHIMS database and use any other sources of information of which you are already aware.

Step 2b: Determine if the activity is in area where landscape features indicate the presence of Aboriginal objects

Step 3: Can you avoid harm to the object or disturbance of the landscape feature?

Step 4: Desktop assessment and visual inspection

Step 5: Further investigation and impact assessment

This report documents the results of a Due Diligence archaeological assessment of the Wakehurst Parkway Flood Mitigation project.

The report was commissioned by Northern Beaches Council.

1.2 Contributors

Field inspection of the study area was undertaken on Friday 26th October 2018 by Jasmine Fenyvesi (NOHC), Joel Mason (NOHC), and Kevin Telford (Metro LALC).

This report was prepared by Jasmine Fenyvesi and internal review was completed by Nicola Hayes.

1.3 This Report

1.3.1 Outline

This report:

- Describes the Due Diligence assessment process (Section 1);
- Describes the proposed works (Section 2);

- Describes the methodology employed in the study, and outlines the results of the data and literature review(Section 3);

- Describes the environmental setting of the study area (Section 4);

- Describes the results of the data review, field survey and Aboriginal consultation program conducted in the context of the assessment (Section 5 and 6); and

- Provides management recommendations based on the results of the investigation (Section 7).

1.3.2 Restricted Information

Information in this report relating to the exact location of Aboriginal sites should not be published or promoted in the public domain. The following images and report sections should be restricted in a public version of this document:

- Figure 3.1;

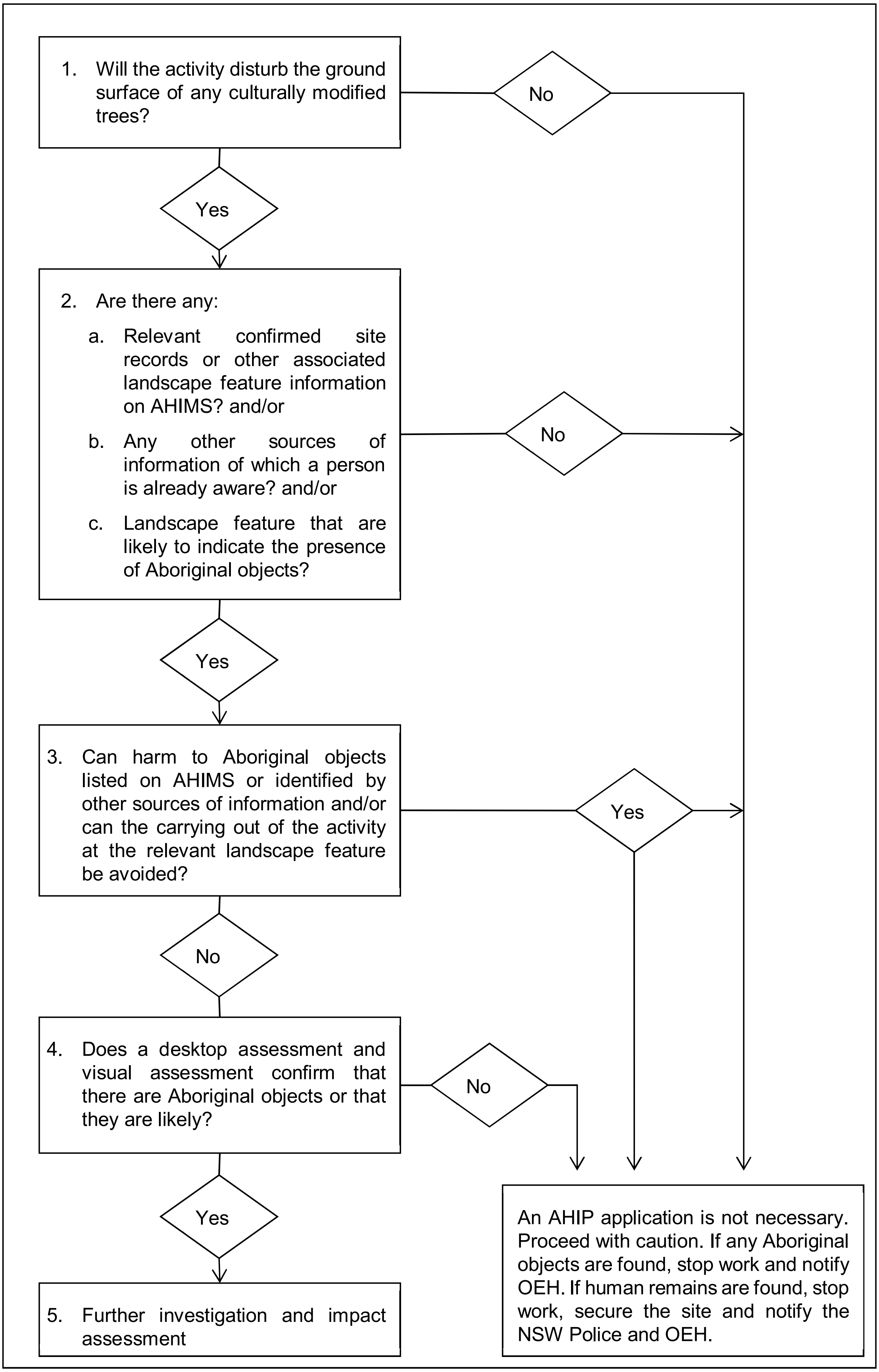
- Section 3.2 (grid references and site location information); and

- Appendix 1 (AHIMS Searches)

No information provided by Aboriginal stakeholders in this report has been specifically identified as requiring access restrictions due to its cultural sensitivity.

1.3.3 Confidentiality

No information in this report has been classified as confidential.



1. Will the activity disturb the ground surface of any culturally modified trees?

2. Are there any:
   a. Relevant confirmed site records or other associated landscape feature information on AHIMS? and/or
   b. Any other sources of information of which a person is already aware? and/or
   c. Landscape feature that are likely to indicate the presence of Aboriginal objects?

3. Can harm to Aboriginal objects listed on AHIMS or identified by other sources of information and/or can the carrying out of the activity at the relevant landscape feature be avoided?

4. Does a desktop assessment and visual assessment confirm that there are Aboriginal objects or that they are likely?

5. Further investigation and impact assessment

An AHIP application is not necessary. Proceed with caution. If any Aboriginal objects are found, stop work and notify OEH. If human remains are found, stop work, secure the site and notify the NSW Police and OEH.

Figure 1.1 Generic due diligence process (from DECCW 2010)

2 PROJECT DESCRIPTION

Wakehurst Parkway is one of the main connecting roads in the Northern Beaches, running from Narrabeen, through Frenchs Forest, to North Balgowlah. It is approximately 17kms from the Sydney CBD. The current project is focused on the 4.5 kilometre stretch of road running alongside Middle Creek, from Oxford Falls to Narrabeen Lagoon, where regular flooding occurs, causing the road to be closed.

Three locations in particular have been identified as problematic areas for over-road flooding:

- The Sports Academy;
- The Bends; and
- Oxford Falls.

As part of works to counteract these flooding occurrences the Northern Beaches Council has proposed a series of flood mitigation options. Sediment removal from Middle Creek at The Bends, culvert upgrades, levee implementation and modification, and stream channel creation or widening are all being considered as viable options at this stage.

A series of environmental investigations have been undertaken for the project in order to assess the various flood mitigation options including the following:

- Detailed creek/ ground survey and bathymetric survey;
- Sediment and geomorphic study;
- Ecology and biodiversity study; and
- Flood mitigation options development study.

2.1 Will the activity disturb the ground surface? (Step 1)

The Wakehurst Parkway Flood Mitigation project may disturb the ground via the following construction activities:

- sediment removal of 1 or 2 metres depth across ~25,000 metre square area;
- culvert upgrades; and
- channel and levee modifications.

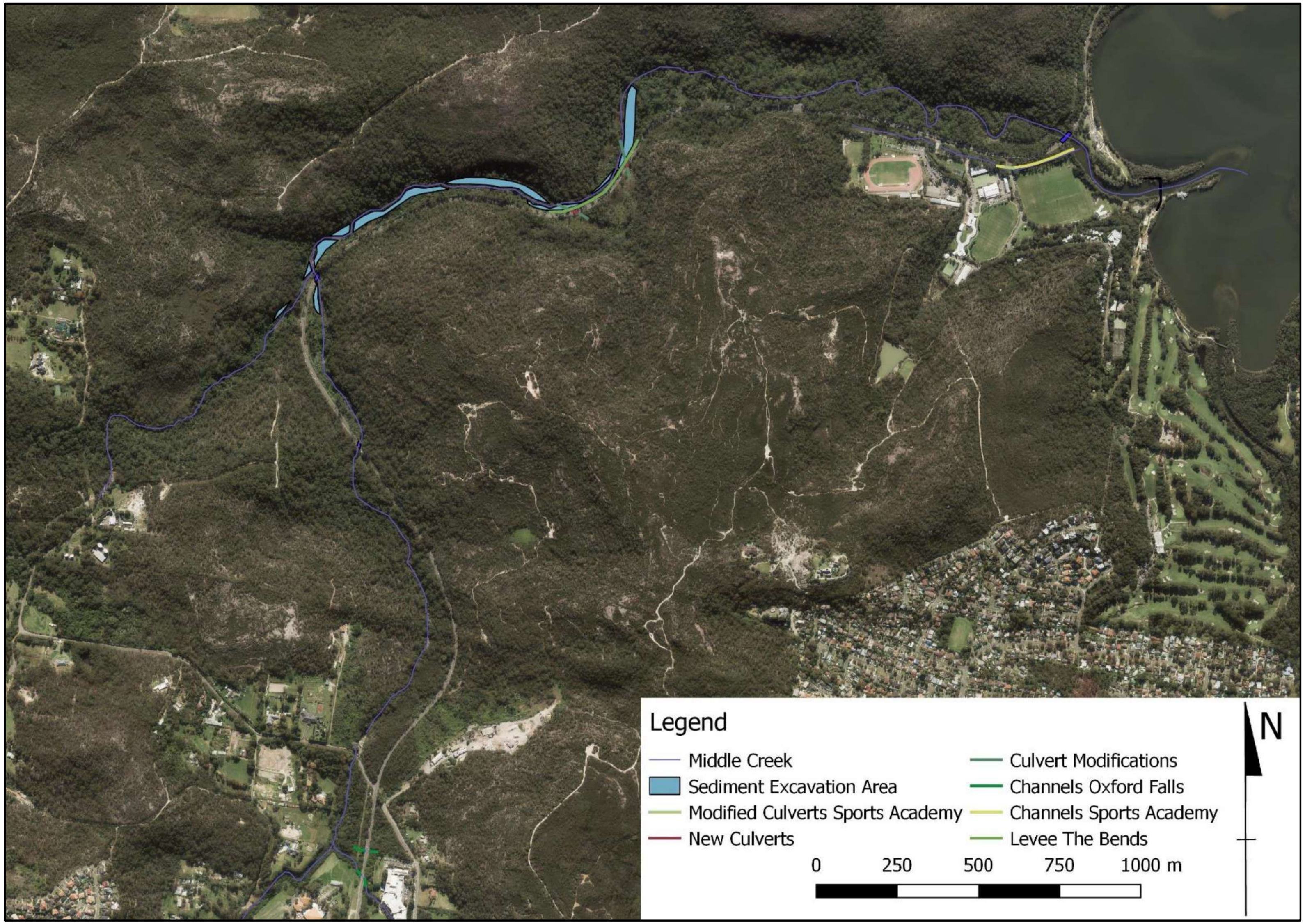


Figure 2.1 Wakehurst parkway Flood Mitigation Project Study Area

3 AHIMS SEARCH AND LITERATURE REVIEW

3.1 Methodology

A range of archaeological and historical data was reviewed for the Wakehurst Parkway study area and its surrounds. The literature and data review was used to determine if known Aboriginal and historical sites were located within the area under investigation, to facilitate site prediction on the basis of known regional and local site patterns, and to place the area within an archaeological and heritage management context. The review of documentary sources included heritage registers and schedules, local histories, and archaeological reports.

Aboriginal literature sources included the Aboriginal Heritage Information Management System (AHIMS) maintained by the NSW Office of Environment and Heritage (OEH) and associated files and catalogue of archaeological reports. Sources of historical information included regional and local histories, heritage studies and theses; parish maps; and where available, other maps, such as portion plans.

Searches were undertaken of the following statutory and non-statutory heritage registers and schedules:

- Aboriginal Heritage Information Management System (AHIMS) (NSW OEH);
- Atlas of Aboriginal Places (NSW OEH); and
- Heritage Schedule(s) attached to relevant Local Environmental Plans.

3.2 AHIMS Search Results

Fifty-eight Aboriginal site recordings and an Aboriginal place are listed on the OEH AHIMS for the area around the Wakehurst Parkway study area within the following (MGA/GDA) map grid references:

Lat, Long From : -33.7434, 151.2278

Lat, Long To : -33.7102, 151.2804

Sites comprise:

- 33 rock engraving sites;
- 6 shelters with art;
- 4 Potential Archaeological Deposits (PADs);
- 4 isolated finds;
- 4 art sites;
- 3 stone arrangements;
- 2 shelters with deposit;
- a quarry;
- a burial;
- a habitation structure; and
- an open camp site.

A copy of the AHIMS search is provided in Appendix 1.

No AHIMS listed sites are located within the current study area.

3.3 Previous Aboriginal Archaeological Research

In 1982, L. Haglund undertook a survey of the Wakehurst Parkway for a proposed pipeline that would run parallel with the road. It covered a distance of 3.4km, from the intersection of Middle Creek and Oxford Falls Rd heading north. She noted a number of small potential rock shelters along the rockfaces bordering the mouths of tributaries but found no sites alongside the parkway.

An archaeological survey of the floodplains was undertaken by McDonald in 1988 (1993), as well as an additional survey conducted by Gunn of the creek lines and alluvial flats within the Narrabeen area (1992). Neither survey identified any Aboriginal sites.

Archaeological investigations of the parkway are limited, however, a large number of sites were recorded within Garigal National Park, to the west of the parkway, and the surrounding area prior to the 1980's. A large number of the, roughly, 40 sites were recorded by government surveyor W.D. Campbell in the late 1800's and amateur archaeologist W. Bluff in the 1970's and 1980's (Gunn 1992, McDonald 2008).

Gunn (1992) conducted a survey of Garigal National park, revisiting a number of the previously recorded sites, and was able to conclude that out of 39 recorded sites 31 of these were considered to be reliable. Engravings, Rock Shelter Art, and Rock Shelter Occupation sites were the main site types encountered in the park, typical of the geology of the region. Gunn estimated that there were still a large number of sites yet to be discovered within the park.

3.4 Heritage Listed Items

Local Heritage items listed under Warrinngah Local Environment Plan (2011):

- Middle Creek Bridge No. 1 (I150)
- Middle Creek Bridge No. 2 (I151)
- Bridge No. 3 over Middle Creek (I146)

Local Archaeological Site listed under Warrinngah Local Environment Plan (2011):

- Ruins of Never Been Beaten Lime and Cement Works (A2)

Items I150 and A2 do not sit within the area of any planned works and should not be impacted. Items I146 and I151 sit in close proximity to planned works at the Sports Academy and The Bends, 10 metres and 30 metres respectively, however there are no plans for the bridges to be impacted by the works (see figure 3.2).

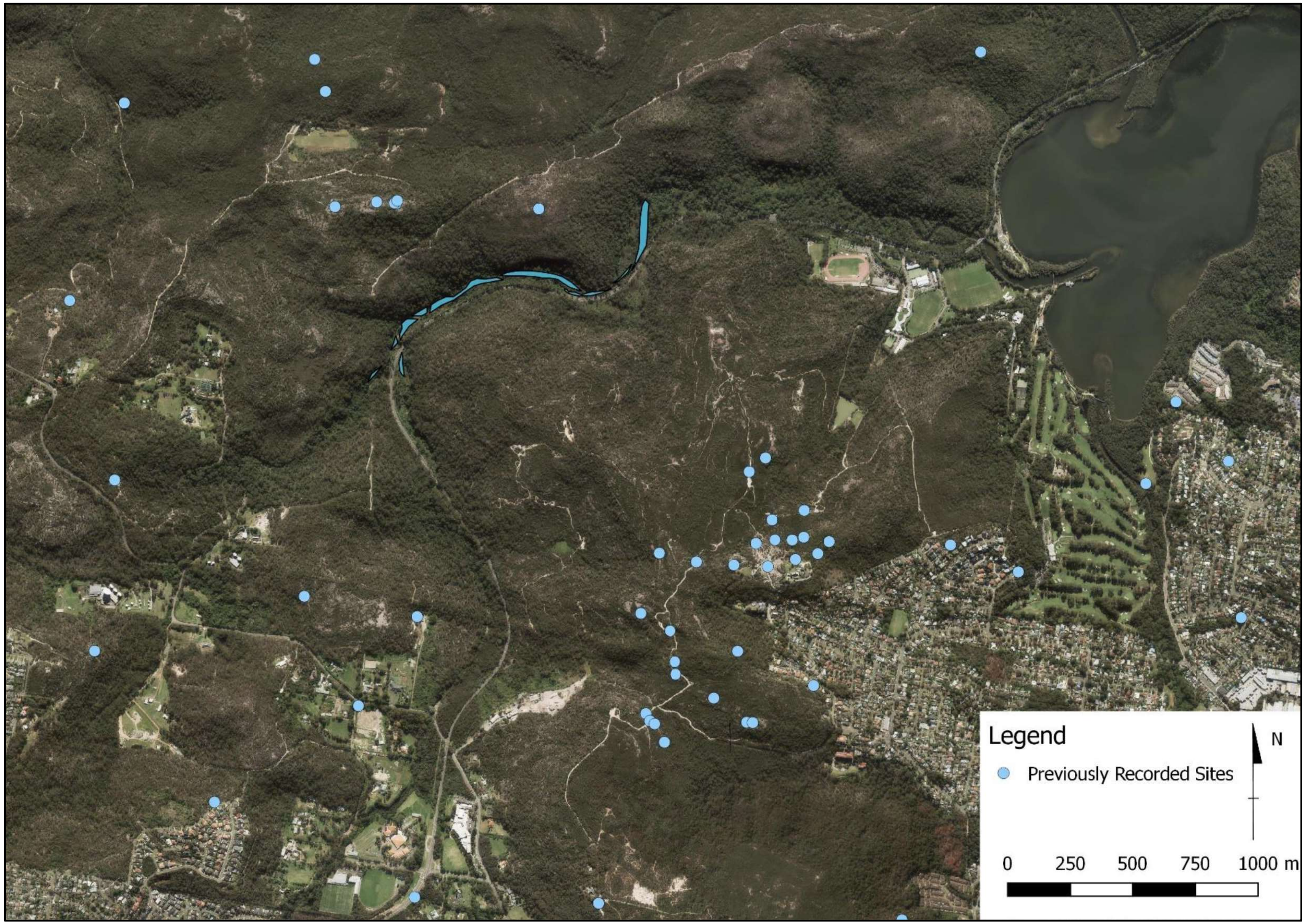


Figure 3.1 Previously Recorded Sites

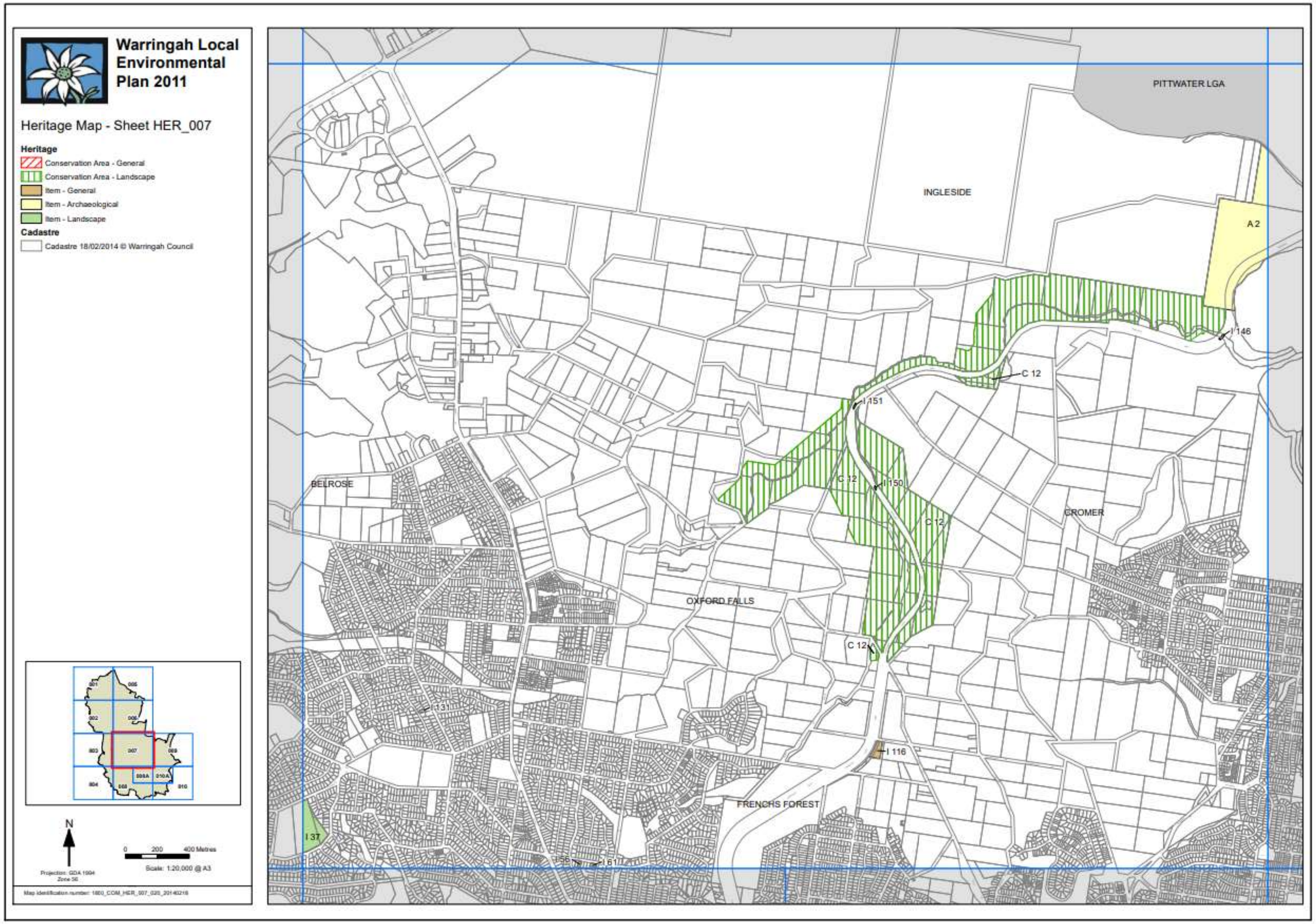


Figure 3.2 Heritage Listed Items (map courtesy of Warringah LEP, 2011)

4 LANDSCAPE CONTEXT

4.1 Landform, Geology, and Vegetation

The Wakehurst Parkway is located on the Northern coastal (Hornsby) plateau of the Hawkesbury sandstone country

Middle Creek is a category 3 stream, with a catchment of approximately 13 kilometres, draining into Narrabeen Lagoon. Elevation is at sea level at the mouth of Middle creek as it enters Narrabeen lagoon. Middle Creek is prone to 'flash flooding' due to the steep surrounding topography of the Hawkesbury Sandstone formation.

Primary rock found in the subject area is Triassic Hawkesbury Sandstone, however, Wianamatta Shales also occur. Erosion of the Sandstone has produced rock platforms, rock shelters, and other rock formations.

Large deposits of Quaternary Alluvium have accumulated in the valleys over the last 100 years. This appears to have stemmed from a single event of massive sand deposit, which may have been dislodged from the hillslopes possibly as a result of fires. The bulk of the sediment has been transported downstream and deposited on the floodplains and has built up to a depth of at least 1m in some areas.

Modelling suggests that the pre-1750's ecology of the Middle Creek riparian zone would have been comprised of Costal Swamp Forest in the lower reaches of the riparian zone and Sydney Sandstone Gully Forrest in the middle to upper reaches (Ecological, 2009).

There have been three principle vegetation classes identified in the wider area surrounding Wakehurst parkway (Gunn, 1992);

- Closed/ open scrub/ woodland along ridge crests and slopes;
- Low woodland in upper gullies; and
- Woodland/ open forest along the alluvial flats

4.2 Landscape History

The Narrabeen area was first settled by a solider named Reynolds who came over with the first fleet (Gunn 1992). Settlement grew throughout the early 1800's, the surrounding land was subject to market gardening, clearing, and low intensity farming.

The woodlands surrounding Deep Creek, which intersects with Wakehurst Parkway north of the main subject area, were subject to timber harvesting

Narrabeen Lakes had extensive shell beds which were dredged for the production of lime, a kiln was set up on the western shore of the lake, west of the Deep Creek entrance.

The growth of Narrabeen and surrounding suburbs in the early 1900's necessitated the construction of the Wakehurst Parkway in the 1940's as a major connecting road. Running between North Balgowlah and Narrabeen, the parkway has had the largest impact on the landscape of the area between Oxford Falls and Narrabeen lagoon, where it runs alongside Middle Creek. .

Due to the change in environment from European land use practises, namely the construction of the Wakehurst Parkway, the surrounding environment has changed substantially. This is particularly visible at The Bends, with high levels of sediment build up on the northern side of the road and a major shift in environment from on the southern side of the road from a riverine environment to a wetland environment (Ecological, 2009).

Figure 4.1 Car buried by the high level of recent sediment deposition

4.3 Is the activity in an area where landscape features indicate the presence of Aboriginal objects?

No surface Aboriginal objects were identified during the visual assessment and no previously recorded sites are located in the project area.

Previous investigations in the area surrounding the Wakehurst Parkway indicate that Aboriginal sites are likely to be found at higher altitudes on the rocky escarpments and are rarely found in the valleys. This dispersal of sites is likely not representative of the movement by Aboriginal people but rather a consequence of development in the area, such as the parkway and suburbs such as Narrabeen, which have likely destroyed a large number of occupational sites (Gunn 1992).

The vegetation native to the area surrounding Middle Creek indicate that this would have been an area utilised by Aboriginal people. Along the alluvial flats of Middle Creek a number of known food plants can be sourced including; Xanthorrhoea (nectar), cabbage palm (young leaves), Lillypilly (fruit), tree fern (pith), soft tree fern (pith), bracken (rhizome and young shoots), and orchid bulbs (Gunn 1992). A number of plants used to make wooden implements can be found in the surrounding study area; stringybark and paperbark (baskets), Xanthorrhoea (spears, fishing and hunting), casuarina (bark canoes), and kurrajong (fishing line). (Gunn 1992).

There are no local stone sources suitable for stone tool manufacturing. It is unlikely that people would have used this area for stone tool production.

The build up of sediment and the changes to the environment in the area surrounding The Bends have obscured any areas that could have held archaeological potential. European land disturbance have also greatly impacted on the other two study areas, Oxford Falls and the Sports Academy.

Figure 4.2 Oxford Falls study area facing north

Figure 4.3 The Bends study area facing south, southern side of road

Figure 4.4 The Bends study area facing west, northern side of road

Figure 4.5 The Sports Academy study area facing west

5 VISUAL ASSESSMENT

5.1 Results

No Aboriginal or non-Aboriginal sites were located during the field survey

Fifty-eight Aboriginal site recordings and an Aboriginal place are listed on the OEH AHIMS for the wider area surrounding the Wakehurst Parkway. None are located in close proximity to the study areas. The closest site is located over 250 metres away from The Bends.

Two locally listed historic sites sit in close proximity to the study area. Middle Creek Bridge No. 2 (I151) sits 10 metres away from the sediment removal area, and Bridge No. 3 over Middle Creek (I146) sits 25 metres away from a proposed channel at the Sports Academy. There are no plans for the heritage sites to be impacted by the proposal.

5.2 Field Methodology

Field Inspection of the study areas was undertaken on Friday 26th October 2018 by Jasmine Fenyvesi (NOHC), Joel Mason (NOHC), and Kevin Telford (Metro LALC).

The study areas were inspected for artefacts, ground surface exposures, vegetation cover, ground conditions and likely soil depth and characteristics.

5.3 Survey Coverage and Visibility Variables

No aboriginal or historical sites or areas of archaeological potential were identified in the Wakehurst Parkway study areas.

The visibility across the study area was low <10% due to vegetation cover, sediment build up, and introduced gravels from the road surface as well as various other impacts of the road.

The project study area has been heavily disturbed through past land use. It is therefore concluded that there is little or no archaeological potential within the current project study area.

6 IMPACT ASSESSMENT AND RECOMMENDATIONS

6.1 Can harm be avoided?

There will be no direct impacts to Aboriginal and historical heritage items.

The flood mitigation study area is located adjacent to heritage listed items Middle Creek Bridge No. 2 (I151) and Bridge No. 3 over Middle Creek (I146). No heritage items will be directly impacted by the current project. Changes to the current project outline may have visual and indirect impacts to the item.

6.2 Recommendations

It is recommended that:

1. No further archaeological assessment is required for the Wakehurst Parkway Flood Mitigation project.

2. The unanticipated discovery protocols included in Appendix 2 should be put in place for the project.

3. A copy of this report should be provided to the Metro Local Aboriginal Land Council.

7 REFERENCES

Ecological 2009 Middle Creek- Management Plan. Report to Warringah Council.

Gunn, R.G. 1992 Garigal National Park Archaeological Survey. A report to NPWS.

Haglund, L. 1982 Report on Survey for Archaeological Relics on the Wakehurst Parkway Route, Frenchs Forest, Sydney, N.S.W. A report to MWS & DB.McDonald, B. 199. Archaeological Survey near Narrabeen Lakes – Middle Creek EIS. A report to Paterson Britton & Partners on behalf of Warringah Council.

NSW DECCW 2010 Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales.

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APPENDIX 1

AHIMS AND OTHER HERITAGE REGISTER SEARCH RESULTS

AHIMS Web Services (AWS)

Search Result

Purchase Order/Reference : Wakehurst parkway

Client Service ID : 369136

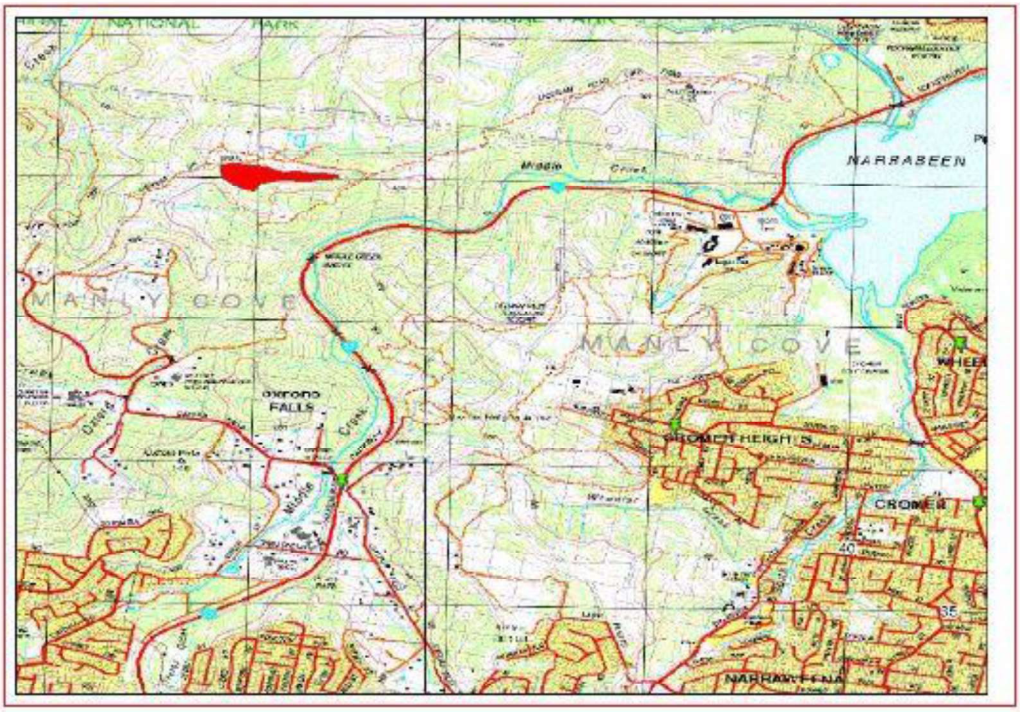
Navin Officer Heritage Consultants Pty Ltd
4/71 Leichhardt Street
Kingston Australian Capital Territory 2604
Attention: Nicola Hayes
Email: nhayes@nohc.com.au

Date: 07 September 2018

Dear Sir or Madam:

AHIMS Web Service search for the following area at Lat, Long From : -33.7434, 151.2278 - Lat, Long To : -33.7102, 151.2804 with a Buffer of 0 meters, conducted by Nicola Hayes on 07 September 2018.

The context area of your search is shown in the map below. Please note that the map does not accurately display the exact boundaries of the search as defined in the paragraph above. The map is to be used for general reference purposes only.



A search of the Office of the Environment and Heritage AHIMS Web Services (Aboriginal Heritage Information Management System) has shown that:

58	Aboriginal sites are recorded in or near the above location.
1	Aboriginal places have been declared in or near the above location. *

ID	Aboriginal Place Name
114	Moon Rock

AHIMS Web Services (AWS)

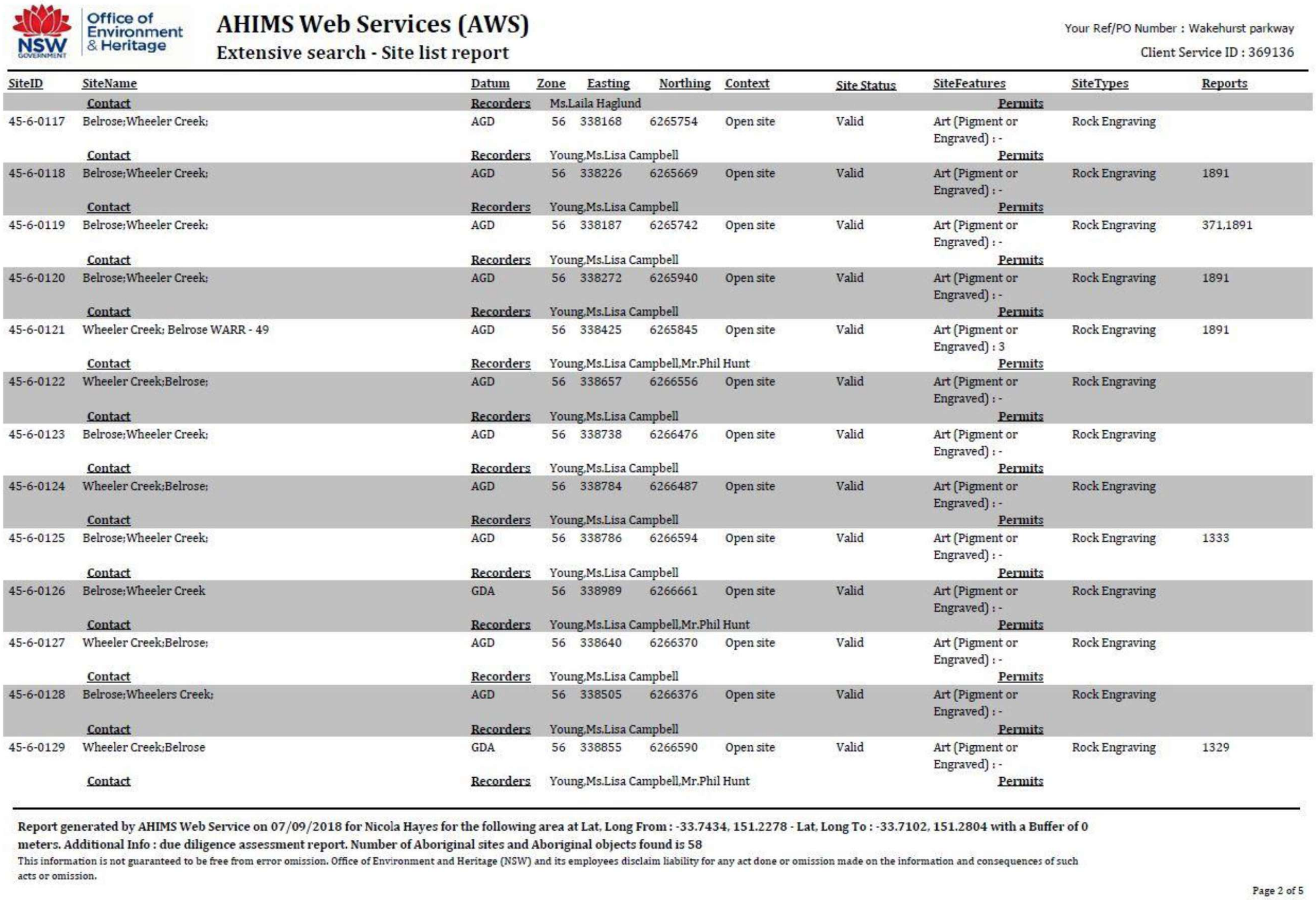
Extensive search - Site list report

Your Ref/PO Number : Wakehurst parkway

Client Service ID : 369136

SiteID	SiteName	Datum	Zone	Easting	Northing	Context	Site Status	SiteFeatures	SiteTypes	Reports
45-6-2219	Cromer Shelter;	GDA	56	339744	6266540	Closed site	Valid	Art (Pigment or Engraved) : -	Shelter with Art	1907
	Contact	Recorders	Mary Dallas Consulting Archaeologists,Mr.Phil Hunt					Permits		
45-6-2274	Frenchs Forest - (refer to 45-6-1273)	AGD	56	337195	6264955	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Mr.Phil Hunt,Melanie Kennedy					Permits		
45-6-2315	GA-2;Garrigal NP;	GDA	56	337829	6267989	Closed site	Valid	Art (Pigment or Engraved) : -	Shelter with Art	2227
	Contact	Recorders	Robert "Ben" Gunn					Permits		
45-6-2318	Dharug N.P.;	AGD	56	336070	6268220	Closed site	Valid	Art (Pigment or Engraved) : -	Shelter with Art	1333
	Contact	Recorders	Warren Bluff					Permits		
45-6-1273	Belrose.	AGD	56	337230	6265050	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1891
	Contact	Recorders	Mr.Phil Hunt,Charles.D Power					Permits		
45-6-1275	Belrose;	AGD	56	337270	6264946	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	ASRSYS					Permits		
45-6-2465	Oxford Falls 1;	AGD	56	335952	6266033	Open site	Valid	Artefact : -	Isolated Find	3462
	Contact	Recorders	Mr.Matthew Barber					Permits		
45-6-0563	Wheeler Creek;Mona Vale;	AGD	56	338152	6265783	Closed site	Valid	Artefact : -	Shelter with Deposit	
	Contact	Recorders	Ms.Bronwyn Conyers,L Hoad,Neil Stone					Permits		
45-6-1160	Oxford Creek	AGD	56	337240	6266170	Open site	Not a Site	Art (Pigment or Engraved) : -	Not an Aboriginal Site	
	Contact	Recorders	Young,M Young					Permits		
45-6-2197	Morgan Road 3;	GDA	56	336136	6266907	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Michael Guider					Permits		
45-6-2336	Red Hill, Narraweena 2	AGD	56	338269	6265990	Open site	Valid	Artefact : -	Open Camp Site	
	Contact	Recorders	Michael Guider,Mr.Phil Hunt					Permits		
45-6-2337	Red Hill, Narraweena 1	AGD	56	337964	6265026	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Michael Guider					Permits		
45-6-0110	Narrabeen;	AGD	56	339489	6268424	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Fred McCarthy					Permits		
45-6-1493	Belrose	AGD	56	338823	6265895	Closed site	Valid	Artefact : -	Shelter with Deposit	940,2010

Report generated by AHIMS Web Service on 07/09/2018 for Nicola Hayes for the following area at Lat, Long From : -33.7434, 151.2278 - Lat, Long To : -33.7102, 151.2804 with a Buffer of 0 meters. Additional Info : due diligence assessment report. Number of Aboriginal sites and Aboriginal objects found is 58



AHIMS Web Services (AWS)

Extensive search - Site list report

Your Ref/PO Number : Wakehurst parkway

Client Service ID : 369136

SiteID	SiteName	Datum	Zone	Easting	Northing	Context	Site Status	SiteFeatures	SiteTypes	Reports
	Contact	Recorders	Ms.Laila Haglund					Permits		
45-6-0117	Belrose;Wheeler Creek;	AGD	56	338168	6265754	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0118	Belrose;Wheeler Creek;	AGD	56	338226	6265669	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1891
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0119	Belrose;Wheeler Creek;	AGD	56	338187	6265742	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	371,1891
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0120	Belrose;Wheeler Creek;	AGD	56	338272	6265940	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1891
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0121	Wheeler Creek; Belrose WARR - 49	AGD	56	338425	6265845	Open site	Valid	Art (Pigment or Engraved) : 3	Rock Engraving	1891
	Contact	Recorders	Young,Ms.Lisa Campbell,Mr.Phil Hunt					Permits		
45-6-0122	Wheeler Creek;Belrose;	AGD	56	338657	6266556	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0123	Belrose;Wheeler Creek;	AGD	56	338738	6266476	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0124	Wheeler Creek;Belrose;	AGD	56	338784	6266487	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0125	Belrose;Wheeler Creek;	AGD	56	338786	6266594	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1333
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0126	Belrose;Wheeler Creek	GDA	56	338989	6266661	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Young,Ms.Lisa Campbell,Mr.Phil Hunt					Permits		
45-6-0127	Wheeler Creek;Belrose;	AGD	56	338640	6266370	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0128	Belrose;Wheelers Creek;	AGD	56	338505	6266376	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0129	Wheeler Creek;Belrose	GDA	56	338855	6266590	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1329
	Contact	Recorders	Young,Ms.Lisa Campbell,Mr.Phil Hunt					Permits		

Report generated by AHIMS Web Service on 07/09/2018 for Nicola Hayes for the following area at Lat, Long From : -33.7434, 151.2278 - Lat, Long To : -33.7102, 151.2804 with a Buffer of 0 meters. Additional Info : due diligence assessment report. Number of Aboriginal sites and Aboriginal objects found is 58

Office of Environment & Heritage

AHIMS Web Services (AWS)

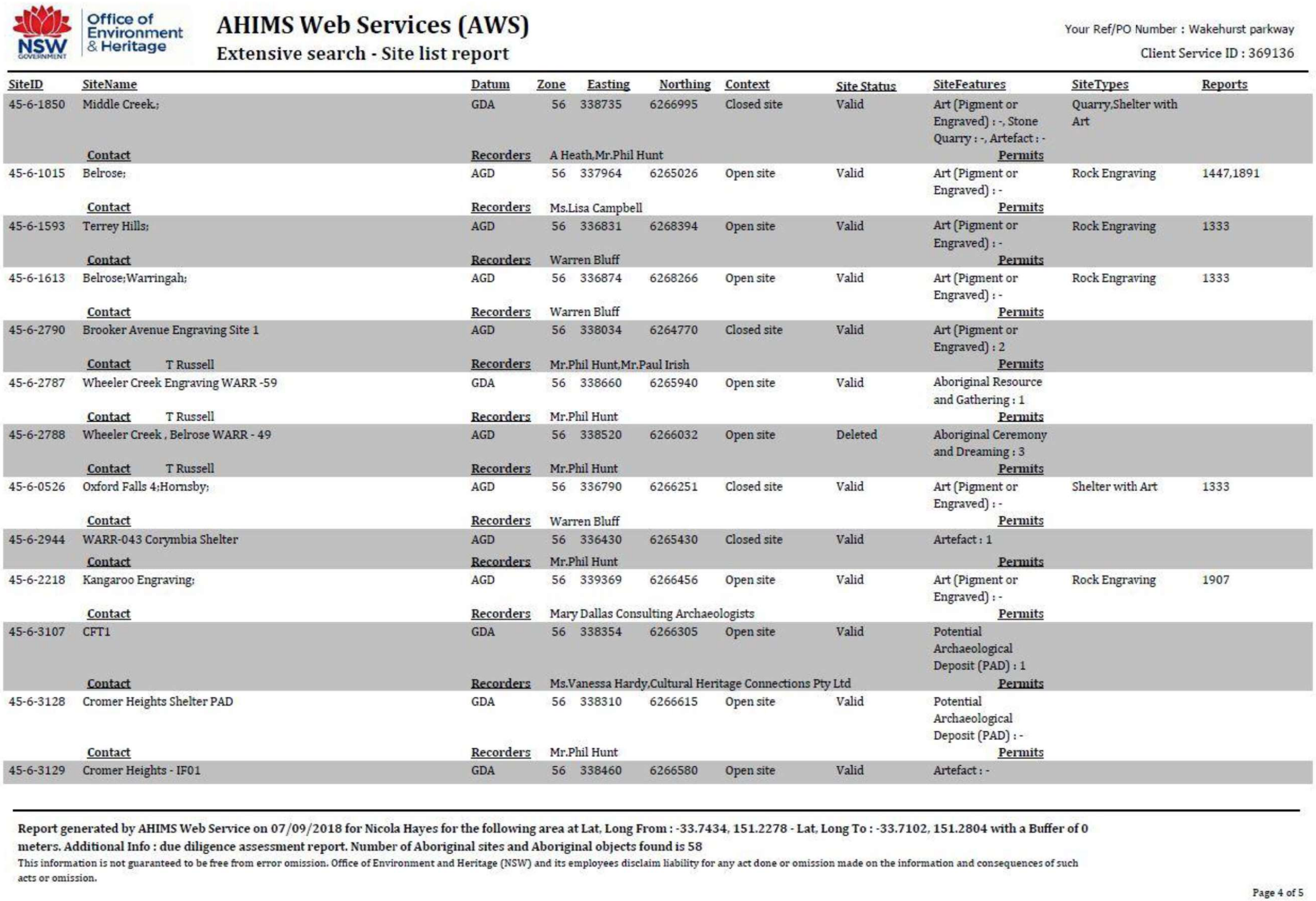
Extensive search - Site list report

Your Ref/PO Number : Wakehurst parkway

Client Service ID : 369136

SiteID	SiteName	Datum	Zone	Easting	Northing	Context	Site Status	SiteFeatures	SiteTypes	Reports
45-6-0303	Belrose;	AGD	56	337006	6265814	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1891
	Contact	Recorders	Young,W Walton					Permits		
45-6-0224	Belrose (Moon Rock)	AGD	56	337079	6267825	Open site	Valid	Stone Arrangement : -, Art (Pigment or Engraved) : -	Rock Engraving,Stone Arrangement	2212
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0225	Belrose (Moon Rock) A	AGD	56	337161	6267830	Open site	Valid	Art (Pigment or Engraved) : -, Stone Arrangement : -	Rock Engraving,Stone Arrangement	371,2212
	Contact	Recorders	Young,Ms.Lisa Campbell					Permits		
45-6-0082	Collaroy;Long Reef Ridge;Group 44;	AGD	56	340530	6266166	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Fred McCarthy					Permits		
45-6-0083	Collaroy;Long Reef Ridge;Group 44;	AGD	56	340150	6266701	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	Fred McCarthy					Permits		
45-6-0088	War Veterans Estate, Narrabeen	AGD	56	340480	6266790	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	4539
	Contact	Recorders	Kate Sullivan					Permits		
45-6-0089	Belrose;Wheelers Creek;Group 121;	AGD	56	338580	6265747	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	
	Contact	Recorders	J.C Lough					Permits		
45-6-0092	Narrabeen Lakes;	AGD	56	340270	6267027	Closed site	Valid	Art (Pigment or Engraved) : -	Shelter with Art	
	Contact	Recorders	W Walton					Permits		
45-6-0226	Belrose (Moon Rock) B	AGD	56	336912	6267806	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	371,1891,2212
	Contact	Recorders	Ms.Lisa Campbell					Permits		
45-6-0785	Belrose;	AGD	56	338132	6266183	Open site	Valid	Stone Arrangement : -	Stone Arrangement	1891
	Contact	Recorders	Young,I.M Sim					Permits		
45-6-0822	Belrose;DC/RE;	GDA	56	337260	6268010	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	371,2212
	Contact	Recorders	Young,University of Sydney,Mr.Phil Hunt					Permits		
45-6-0823	Belrose;DC/RFa;	GDA	56	337254	6268012	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	371
	Contact	Recorders	Young,University of Sydney					Permits		

Report generated by AHIMS Web Service on 07/09/2018 for Nicola Hayes for the following area at Lat, Long From : -33.7434, 151.2278 - Lat, Long To : -33.7102, 151.2804 with a Buffer of 0 meters. Additional Info : due diligence assessment report. Number of Aboriginal sites and Aboriginal objects found is 58



AHIMS Web Services (AWS)

Extensive search - Site list report

Your Ref/PO Number : Wakehurst parkway

Client Service ID : 369136

SiteID	SiteName	Datum	Zone	Easting	Northing	Context	Site Status	SiteFeatures	SiteTypes	Reports
45-6-1850	Middle Creek;	GDA	56	338735	6266995	Closed site	Valid	Art (Pigment or Engraved) : -, Stone Quarry : -, Artefact : -	Quarry,Shelter with Art	
	Contact	**Recorders**	A Heath,Mr.Phil Hunt					**Permits**		
45-6-1015	Belrose;	AGD	56	337964	6265026	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1447,1891
	Contact	**Recorders**	Ms.Lisa Campbell					**Permits**		
45-6-1593	Terrey Hills;	AGD	56	336831	6268394	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1333
	Contact	**Recorders**	Warren Bluff					**Permits**		
45-6-1613	Belrose;Warringah;	AGD	56	336874	6268266	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1333
	Contact	**Recorders**	Warren Bluff					**Permits**		
45-6-2790	Brooker Avenue Engraving Site 1	AGD	56	338034	6264770	Closed site	Valid	Art (Pigment or Engraved) : 2		
	Contact T Russell	**Recorders**	Mr.Phil Hunt,Mr.Paul Irish					**Permits**		
45-6-2787	Wheeler Creek Engraving WARR -59	GDA	56	338660	6265940	Open site	Valid	Aboriginal Resource and Gathering : 1		
	Contact T Russell	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-2788	Wheeler Creek , Belrose WARR - 49	AGD	56	338520	6266032	Open site	Deleted	Aboriginal Ceremony and Dreaming : 3		
	Contact T Russell	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-0526	Oxford Falls 4;Hornsby;	AGD	56	336790	6266251	Closed site	Valid	Art (Pigment or Engraved) : -	Shelter with Art	1333
	Contact	**Recorders**	Warren Bluff					**Permits**		
45-6-2944	WARR-043 Corymbia Shelter	AGD	56	336430	6265430	Closed site	Valid	Artefact : 1		
	Contact	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-2218	Kangaroo Engraving;	AGD	56	339369	6266456	Open site	Valid	Art (Pigment or Engraved) : -	Rock Engraving	1907
	Contact	**Recorders**	Mary Dallas Consulting Archaeologists					**Permits**		
45-6-3107	CFT1	GDA	56	338354	6266305	Open site	Valid	Potential Archaeological Deposit (PAD) : 1		
	Contact	**Recorders**	Ms.Vanessa Hardy,Cultural Heritage Connections Pty Ltd					**Permits**		
45-6-3128	Cromer Heights Shelter PAD	GDA	56	338310	6266615	Open site	Valid	Potential Archaeological Deposit (PAD) : -		
	Contact	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-3129	Cromer Heights - IF01	GDA	56	338460	6266580	Open site	Valid	Artefact : -		

Report generated by AHIMS Web Service on 07/09/2018 for Nicola Hayes for the following area at Lat, Long From : -33.7434, 151.2278 - Lat, Long To : -33.7102, 151.2804 with a Buffer of 0 meters. Additional Info : due diligence assessment report. Number of Aboriginal sites and Aboriginal objects found is 58

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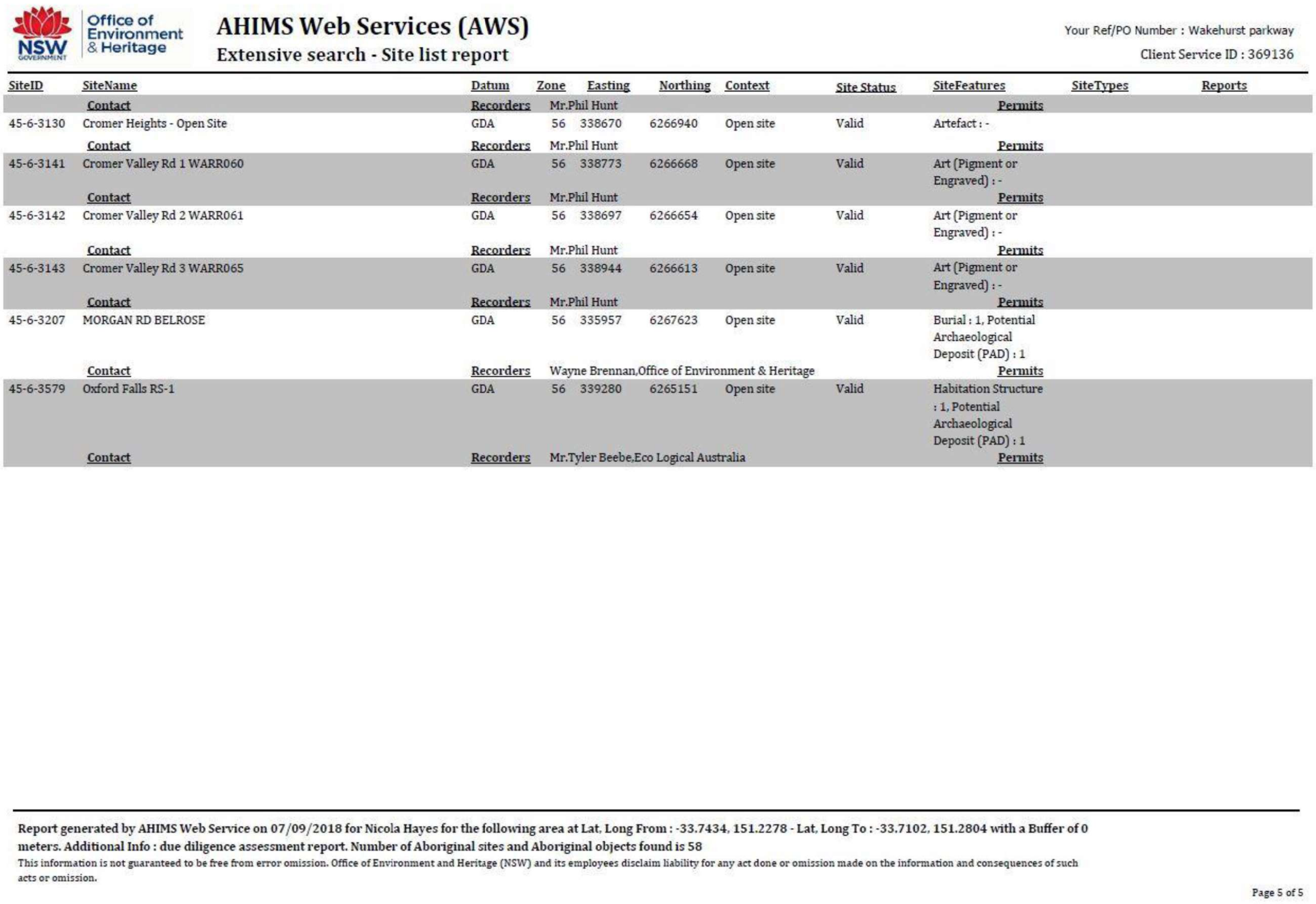

NSW GOVERNMENT Office of Environment & Heritage

AHIMS Web Services (AWS)

Extensive search - Site list report

Your Ref/PO Number : Wakehurst parkway

Client Service ID : 369136

SiteID	SiteName	Datum	Zone	Easting	Northing	Context	Site Status	SiteFeatures	SiteTypes	Reports
	Contact	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-3130	Cromer Heights - Open Site	GDA	56	338670	6266940	Open site	Valid	Artefact : -		
	Contact	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-3141	Cromer Valley Rd 1 WARR060	GDA	56	338773	6266668	Open site	Valid	Art (Pigment or Engraved) : -		
	Contact	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-3142	Cromer Valley Rd 2 WARR061	GDA	56	338697	6266654	Open site	Valid	Art (Pigment or Engraved) : -		
	Contact	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-3143	Cromer Valley Rd 3 WARR065	GDA	56	338944	6266613	Open site	Valid	Art (Pigment or Engraved) : -		
	Contact	**Recorders**	Mr.Phil Hunt					**Permits**		
45-6-3207	MORGAN RD BELROSE	GDA	56	335957	6267623	Open site	Valid	Burial : 1, Potential Archaeological Deposit (PAD) : 1		
	Contact	**Recorders**	Wayne Brennan,Office of Environment & Heritage					**Permits**		
45-6-3579	Oxford Falls RS-1	GDA	56	339280	6265151	Open site	Valid	Habitation Structure : 1, Potential Archaeological Deposit (PAD) : 1		
	Contact	**Recorders**	Mr.Tyler Beebe,Eco Logical Australia					**Permits**		

Report generated by AHIMS Web Service on 07/09/2018 for Nicola Hayes for the following area at Lat, Long From : -33.7434, 151.2278 - Lat, Long To : -33.7102, 151.2804 with a Buffer of 0 meters. Additional Info : due diligence assessment report. Number of Aboriginal sites and Aboriginal objects found is 58

APPENDIX 2

UNANTICIPATED DISCOVERY PROTOCOLS

Protocol to follow in the event that Aboriginal object(s) or historical relics (other than human remains) are encountered and no AHIP has been approved

In the event that object(s) which are suspected of being Aboriginal object(s) or relic(s) are encountered during development works, then the following protocol will be followed:

1. Cease any further excavation or ground disturbance, in the area of the find(s);
    a. The discoverer of the find(s) will notify machinery operators in the immediate vicinity of the find(s) so that work can be temporarily halted; and
    b. The site supervisor and the Principal will be informed of the find(s).
2. Do not remove any find(s) or unnecessarily disturb the area of the find(s);
3. Ensure that the area of the find(s) is adequately marked as a no-go area for machinery or further disturbance, and that the potential for accidental impact is avoided;
4. Note the location and nature of the finds, and report the find to:
    a. Relevant project personnel responsible for project and construction direction and management, and
    b. Report the find to the Office of Environment and Heritage (OEH).
5. Where feasible, ensure that any excavation remains open so that the finds can be recorded and verified. An excavation may be backfilled if this is necessary to comply with work safety requirements, and where this action has been approved by the OEH. An excavation that remains open should only be left unattended if it is safe and adequate protective fencing is installed around it.
6. Following consultation with the relevant statutory authority (OEH), and, where advised, any other relevant stakeholder groups, the significance of the finds should be assessed and an appropriate management strategy followed. Depending on project resources and the nature of the find(s), this process may require input from a consulting heritage specialist.
7. Development works in the area of the find(s) may re-commence, if and when outlined by the management strategy, developed in consultation with, and approved by the relevant statutory authority.
8. If human skeletal material is encountered, the protocol for the discovery of human remains should be followed (refer attached).

Protocol to follow in the event of the discovery of suspected human remains

The following protocol will be actioned if suspected human material is revealed during development activities or excavations:

1. All works must halt in the immediate area of the find(s) and any further disturbance to the area of the find(s) prevented.

    c. The discoverer of the find(s) will notify machinery operators in the immediate vicinity of the find(s) so that work can be halted; and

    d. The site supervisor and the Principal/Project manager will be informed of the find(s).

2. If there is substantial doubt regarding a human origin for the remains, then consider if it is possible to gain a qualified opinion within a short period of time. If feasible, gain a qualified opinion (this can circumvent proceeding further along the protocol for remains which are not human). If conducted, this opinion must be gained without further disturbance to the find(s) or the immediate area of the find(s). (Be aware that the site may be considered a crime scene that retains forensic evidence). If a quick opinion cannot be gained, or the identification is positive, then proceed to the next step.

3. Immediately notify the following of the discovery:

    a. The local Police (this is required by law);

    b. An OEH archaeologist or Aboriginal Heritage Officer;

    c. Representative(s) from the Local Aboriginal Land Council; and

    d. The project archaeologist (if not already notified).

4. Co-operate and be advised by the Police and/or coroner with regard to further actions and requirements concerning the find area. If required, facilitate the definitive identification of the material by a qualified person (if not already completed).

5. In the event that the Police or coroner instigate an investigation, construction works are not to resume in the designated area until approval in writing is gained from the NSW Police.

6. In the event that the Police and/or Coroner advise that they do not have a continuing or statutory role in the management of the finds then proceed with the following steps:

7. If the finds are not human in origin but are considered to be archaeological material relating to Aboriginal occupation then proceed with Protocol for the discovery of Aboriginal objects (other than human remains).

8. If the finds are Aboriginal or probably Aboriginal in origin:

    a. Ascertain the requirements of OEH, the Heritage Branch, the Project Manager, and the views of the Local Aboriginal Land Council, and the project archaeologist.

    b. Based on the above, determine and conduct an appropriate course of action. Possible strategies could include one or more of the following:

        i. Avoiding further disturbance to the find and conserving the remains *in situ*;

        ii. Conducting archaeological salvage of the finds following receipt of any required statutory approvals;

iii. Scientific description (including excavation where necessary), and possibly also analysis of the remains prior to reburial;

iv. Recovering samples for dating and other analyses; and/or

v. Subsequent reburial at another place and in an appropriate manner determined by the Local Aboriginal Land Council.

9. If the finds are non-Aboriginal in origin:

   c. Ascertain the requirements of the Heritage Branch, Project Manager, and the views of any relevant community stakeholders and the project archaeologist.

   a. Based on the above, determine and conduct an appropriate course of action. Possible strategies could include one or more of the following:

      a. Avoiding further disturbance to the find and conserving the remains *in situ*;

      b. Conducting archaeological salvage of the finds following receipt of any required statutory approvals;

      c. Scientific description (including excavation where necessary), and possibly also analysis of the remains prior to reburial;

      d. Recovering samples for dating and other analyses; and/or

      e. Subsequent reburial at another place and in an appropriate manner determined in consultation with the Heritage Office and other relevant stakeholders.

10. Construction related works in the area of the remains (designated area) may not resume until the proponent receives written approval in writing from the relevant statutory authority: from the Police or Coroner in the event of an investigation, from OEH in the case of Aboriginal remains outside of the jurisdiction of the Police or Coroner, and from the Heritage Branch in the case of non-Aboriginal remains outside of the jurisdiction of the Police or Coroner.

APPENDIX 3

STATUTORY AND POLICY CONTEXT[1]

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[1] The following information is provided as a guide only. Readers are advised to seek qualified legal advice relative to legislative matters.

National Parks and Wildlife Amendment Bill 2010

The National Parks and Wildlife Amendment Bill 2010 (also known as the Omnibus Bill), was implemented on 1 October 2010 to amend the *National Parks and Wildlife Act 1974* (NPW Act). Existing offences relating to Aboriginal objects and places were replaced with new offences, including a strict liability offence, along with offence exemptions and defences.

Part 6 of the NPW Act provides specific protection for Aboriginal objects and declared Aboriginal places by establishing offences of harm. Harm is defined to mean destroying, defacing, damaging or moving an object from the land. There are a number of defences and exemptions to the offence of harming an Aboriginal object or place. One of the defences is that the harm was carried out under an Aboriginal Heritage Impact Permit (AHIP).

In practice, archaeologists use a methodology that groups 'Aboriginal objects' into various site classifications according to the nature, occurrence and exposure of archaeological material evidence. The archaeological definition of a site may vary according to survey objectives; however a site is not recognised or defined as a legal entity in the Act.

It should be noted that even single and isolated artefacts are protected as Aboriginal objects under the Act.

In 2010 the *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales* was adopted by clause 3A of the National Parks and Wildlife Regulation 2009 (NPW Regulation). The code allows for the subsurface test excavation of Aboriginal objects without the need for an AHIP. The code establishes the requirements for undertaking test excavation without an AHIP and establishes the requirements that must be followed when carrying out archaeological investigation in NSW where an application for an AHIP is likely to be made.

Additional amendments that commenced on 1 October 2010 include the introduction of new processes for Aboriginal Heritage Impact Permit (AHIP) applications, consultation guidelines to support the Aboriginal Heritage Impact Permits (AHIP) application process, and mechanical provisions such as the transfer and variations of conditions of AHIPs.

NSW Heritage Act 1977 and Heritage Amendment Acts 1998 & 2009

The purpose of these Acts is to ensure that the heritage of New South Wales is adequately identified and conserved. In practice the Acts have focused on items and places of non-indigenous heritage to avoid overlap with the NP&W Act, which has primary responsibilities for nature conservation and the protection of Aboriginal relics and places in NSW.

The *Heritage Amendment Act 1998* came into effect in April 1999. The Act instigated changes to the NSW heritage system, which were the result of a substantial review begun in 1992. A central feature of the amendments was the clarification and strengthening of shared responsibility for heritage management between local government authorities, responsible for items of local significance, and the NSW Heritage Council. The Council retained its consent powers for alterations to heritage items of State significance.

The *Heritage Amendment Act 2009* came into effect in October 2009. The Act includes greater fairness and rigour in the heritage listing process while retaining key elements of the current system, including local and State listings, and the Heritage Council.

One of the changes to the former Heritage Act has been the move from the arbitrary 50 year age-based definition for archaeology, to one based on significance where relics have to demonstrate local or State significance.

Under the *Heritage Act 1977* a 'relic' had been defined as any deposit which related to the European settlement of NSW and was 50 years old or more. This broad definition captured too many items – many of which would not generally be considered part of the State's archaeological heritage. This approach brings archaeological heritage management more consistently within the management of other heritage items, which is based on an assessment of significance. The previous definition of archaeological relic encompassed a significant number of items over 50 years of age that had no heritage value.

The Heritage Act is concerned with all aspects of conservation ranging from the most basic protection against damage and demolition, to restoration and enhancement. It recognises two levels of heritage significance – State and Local significance across a broad range of values.

Some key provisions of the Act are:

- The establishment and functions of the Heritage Council (Part 2);
- Interim heritage orders (Part 3), the State Heritage Register (Part 3A);
- Heritage Agreements (Part 3B);
- Environmental planning instruments (Part 5);
- The protection of archaeological deposits and relics (Part 6); and
- The establishment of Heritage and Conservation Registers for state government owned and managed items (Part 7).

Generally this Act provides protection to items that have been identified, assessed and listed on various registers including State government section 170 registers, local government Local Environmental Plans and the State Heritage Register. The Interim Heritage Order provisions allow the minister or his delegates (local government may have delegated authority) to provide emergency protection to threatened places which have not been previously identified.

In addition, the Act includes provisions which relate to the definition and protection of relics.

APPENDIX E - Ecological Constraints Reports

Ecological Constraints & Impacts have been assessed and presented in the following Niche Report. The following table has been presented to show how the impacts in various areas map to the options presented in the main body of the report, in summary form.

Option	Description	Impacts Assessed	Native Vegetation Area (ha)	Significant Impacts
The Bends				
Option B1	*New levee*	*N/A*	*N/A*	*N/A*
Option B2	*New levee and removal of 1m depth of overbank sediment*	Sediment Removal	2.41	Likely
Option B3	*New levee, removal of 1m depth of overbank sediment and under-road culverts*	Sediment Removal + Bends (culverts)	2.41 + 0.22 = 2.63	Likely
Option B4	*New levee, removal of 1m depth of overbank sediment, under road culverts, and top up of existing levee.*	Sediment Removal + Bends (culverts)	2.41 + 0.22 = 2.63	Likely
Option B5	*Removal of overbank sediment (1m depth)*	Sediment Removal	2.41	Likely
Option B6	*Removal of overbank sediment (2m depth)*	*N/A*	*N/A*	*N/A*
Option B7	*New levee, under road culverts.*	Bends (culverts)	0.22	Likely
Oxford Falls Road				
Option O1	*Culvert capacity increase*	Oxford Falls	0.07	Not likely
Option O2	*Culvert capacity increase (additional to O1)*	Oxford Falls	0.07	Not likely
Sydney Academy of Sport and Recreation				
Option S1	*Bunds and localised low point drainage*	Sportsground	0.77	Likely

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Environment and Heritage

Wakehurst Parkway Flood Mitigation Project

Preliminary Biodiversity Assessment

Prepared for Royal Haskoning DHV | 21 November 2019

Document control

Project number	Client	Project manager	LGA
4604	Royal Haskoning DHV	Matthew Russell	Northern Beaches

Version	Author	Review	Status	Date
D1	Luella Cox, Cairo Forrest	Luke Baker	Draft	05 April 2019
Rev1	Luke Baker	Royal Haskoning DHV	Rev1	19 November 2019

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Tables

Figures

1. Introduction

1.1 Context

Niche Environment and Heritage (Niche) has prepared a preliminary biodiversity assessment for three potential flood mitigation impact sites, and one 'sediment removal' option, associated with the Wakehurst Parkway Flood Mitigation Project. The advice provided will be used to inform the feasibility of each site by providing information regarding biodiversity values and biodiversity offsetting costs associated with each of the options.

1.2 The project

Northern Beaches Council has been granted funding by the state government under the Stronger Communities Fund for the development of flood mitigation solutions along Wakehurst Parkway. Potential three flood mitigation options associated with the funding include:

- Extraction of the top 1 m of sand from the Middle Creek channel from Narrabeen Lagoon to the intersection of Middle Creek with Oxford Creek;
- Extraction of the top 1 m of sand within Middle Creek at Sydney Academy of Sport and Recreation and at the Bends Culverts only with a vegetation management program along the extent of the creek to reduce the presence of weeds and exotic vegetation;
- Upgrade of culverts;
- Dredging at the mouth of Middle Creek, downstream of Wakehurst Parkway;
- Small sediment basins and sediment traps;
- Stabilisation of fire trails;
- Construction of additional sediment control measures in the urban areas;
- Creek restoration to minimise sediment generation; and
- Vegetation removal to assist sediment movement.

The three sites considered for flood mitigation works include areas referred to as 'The Bends Culverts, The Sports Field and Oxley Falls', located within the Northern Beaches Local Government Area (LGA).

Another option, which is referred to as the 'sediment removal' option was also assessed, which entails a 1 m excavation footprint within the floodplain and riparian zone of Middle Creek, as well as enabling works (work areas, access tracks, ramps, etc.). The sediment removal option also occurs within 'The Bends Culverts'.

Collectively these areas are referred to as the 'Study Area' (Figure 1).

Each of these options are split into smaller 'sub-options' as detailed in Royal Haskoning DHV (2019) Wakehurst Parkway Flood Mitigation Feasibility Study, and have been summarised in Table 1.

1.3 Site location and description

The Study Area is located along Wakehurst Parkway within the Northern Beaches LGA (Figure 1). The flood mitigation sites are located immediately adjacent to Wakehurst Parkway road verge, and would require the direct disturbance to native vegetation and introduced vegetation to allow for machinery access to install appropriate sedimentation controls, and rehabilitated portions of Middle Creek.

A summary of the proposed option, including the relationship to the 'sub-options' as detailed in Royal Haskoning DHV (2019), has been provided in Table 1. The location of each of the options are also shown on Figures 2 to Figure 5.

Given the preliminary nature of this assessment, the extent of indirect impacts associated with the proposed works are not known, and as such, the Study Area encompasses the area of direct disturbance provided to Niche by Royal Haskoning DVH. As recommended in section 5, indirect impacts and any associated cumulative works would need to be considered in the overall biodiversity impact assessment for the project once known.

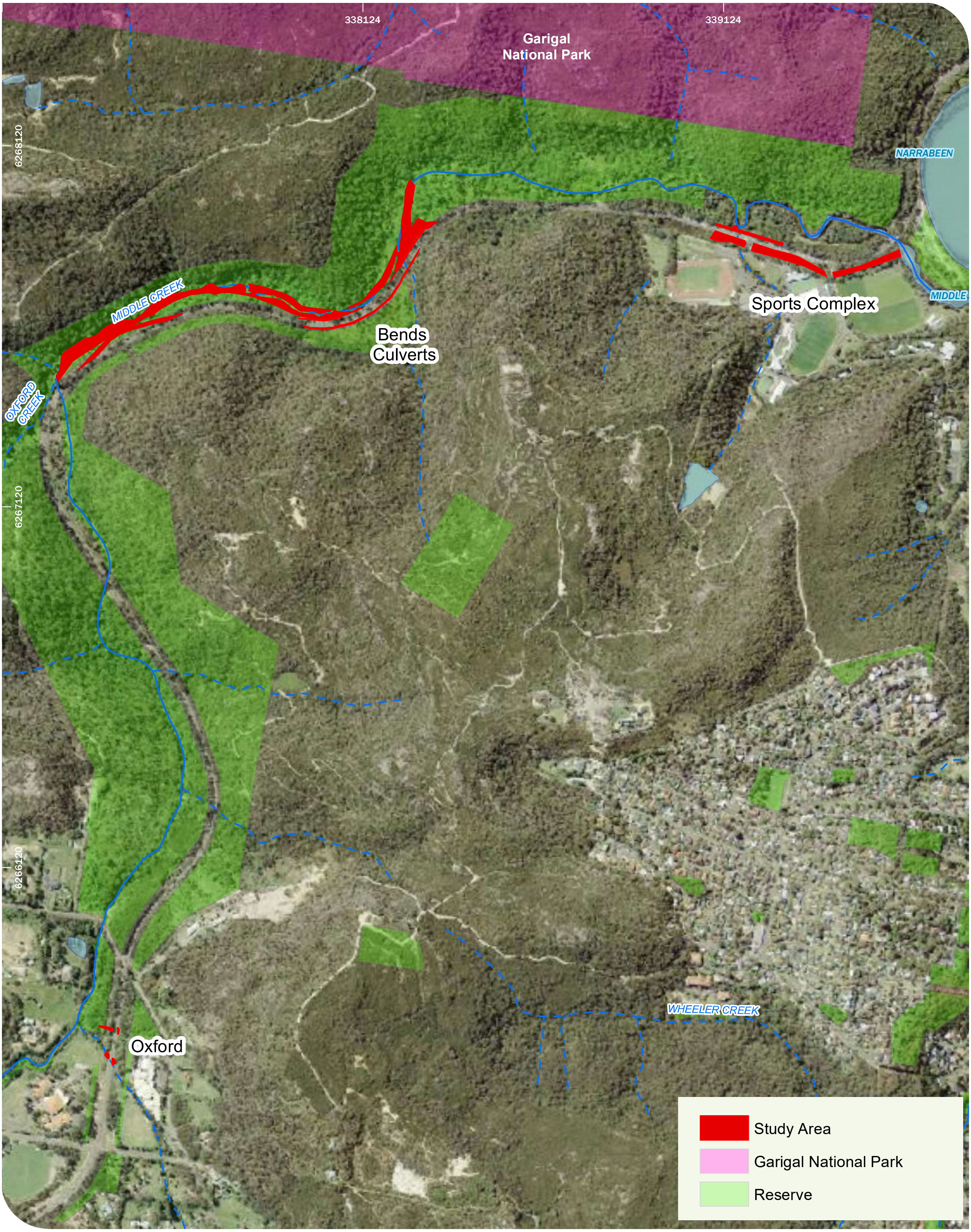
Table 1. Options assessed in this report

Option	Description	Impacts Assessed	Native Vegetation Area (ha)
The Bends option			
Option B2	New levee and removal of 1m depth of overbank sediment	The Bends Culverts 'sediment removal' option	2.88
Option B3	New levee, removal of 1m depth of overbank sediment and under-road culverts	The Bends Culverts 'sediment removal' option and the Bends culverts option	3.10
Option B4	New levee, removal of 1m depth of overbank sediment, under road culverts, and top up of existing levee.	The Bends Culverts 'sediment removal' option and the Bends culverts option	3.10
Option B5	Removal of overbank sediment (1m depth)	The Bends Culverts 'sediment removal'	2.88
Option B7	New levee, under road culverts.	Bends culverts option	0.22
Oxford Falls option			
Option O1	Culvert capacity increase	Oxford Falls	0.07
Option O2	Culvert capacity increase (additional to O1)	Oxford Falls	0.07
Sportsground option			
Option S1	Bunds and localised low point drainage	Sportsground	0.78

1.4 Aims

This report provides advice regarding the constraints of the options from an ecological perspective, which will inform project planning. The report includes a review previous surveys associated with each option, details the biodiversity impacts, and the likely 'significance' of impacts toward biodiversity.

This assessment also provides the indicative biodiversity offsetting costs, should the Biodiversity Offset Scheme (BOS) be triggered.



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niche
Environment and Heritage

GDA 1994 MGA Zone 56

Wakehurst Parkway Flood Mitigation - Ecological Assessment

Overview of study Area

Niche PM: MR
Niche Proj. #: 4604
Client: Northern Beaches Council

Figure 1

public_NSW_Imagery:

2. Methodology

2.1 Approach to the preliminary assessment

The approach to this preliminary assessment has involved the following core tasks, which are described in detail below:

1. Review relevant biodiversity assessments, including GHD (2018) Northern Beaches Council Wakehurst Park Flood Mitigation Biodiversity Constraints Assessment
2. Complete a database search and likelihood of occurrence assessment
3. Field survey to confirm existing vegetation mapping
4. Determine if a significant impact associated with the project is likely
5. Determine the potential offsetting costs associated with each option, including the one sediment removal option.

2.2 Previous Biodiversity Assessments

The options and wider area has been surveyed by GHD (2018) between the 21st of February 2018 and the 9th of April 2018 as part of an initial preliminary biodiversity assessment. In summary, the field survey entailed the following:

Flora

- Ground-truthing vegetation mapping via walked transects across Study Area and walking vegetation boundaries.
- BAM plots (12) to confirm vegetation types, assess site condition and calculate biodiversity credits.
- Targeted threatened flora surveys through desktop assessment and during all transects and plot surveys. Potential habitat was noted based on OEH species profiles and knowledge.
- Weed mapping and identification during transects and plots for all priority and significant patches.

Fauna

- Five dawn bird surveys, targeted surveys in late afternoon. Diurnal surveys for migratory waders, plus all opportunistic observations throughout survey period.
- Targeted searches for Red Crowned Toadlet plus opportunistic occurrences of more common species recorded through study period. Habitat assessment specifically for Red-crowned Toadlet habitat plus call playbacks.
- Omnivorous baited infra-red cameras were placed across 6 sites for a two week period at each (3 sites at a time), targeting arboreal mammals including Eastern Pygmy Possum (*Cercartetus nanus*) and the Spot-tailed Quoll (*Dasyurus maculatus*).
- Anabat surveys over 4 nights at three sites. Call recognition done using guides and known species distribution.
- Culverts inspected opportunistically for guano, roosting bats and habitat potential.
- Opportunistic inspections of overhangs, crevices and undersides of bridges for any fauna.
- Hollow bearing trees were mapped, targeted for larger hollows with habitat potential for owls.
- Stag watches, call playbacks and spotlighting occurred over three evenings for a period of 3-3.5 hours each.

Key conclusions from the report have been incorporated throughout this assessment where relevant.

2.3 Database and literature sources

Relevant databases were reviewed prior to field survey to identify data gaps and inform survey design. Database searches for a 10 km radius around the Study Area were conducted in January 2019 to identify threatened biodiversity and migratory species with known occurrences in the locality. The following databases and literature were used for this purpose:

- Office of Environment and Heritage (OEH) BioNet, Atlas of NSW Wildlife (OEH 2019a)
- Department of the Environment and Energy (DoEE) EPBC Act Protected Matters Report (DoEE 2019)
- Threatened Species Profiles for threatened species, endangered populations and threatened ecological communities (TECs) listed under the BC Act (OEH 2019b).

A list of subject threatened flora and fauna within the locality (10 km radius) was determined from database searches. Threatened species with potential to occur in the Study Area are determined from consideration of this list.

Five categories for 'likelihood of occurrence' (Table 2) were attributed to species after consideration of criteria such as known records, presence or absence of important habitat features in the Study Area, results of the field surveys and professional judgement. This process was completed on an individual species basis.

Table 2: Likelihood of occurrence criteria

Likelihood rating	Threatened flora criteria	Threatened and migratory fauna criteria
Known	The species was observed within the Study Area.	The species was observed within the Study Area.
High	It is likely that a species inhabits or utilises habitat within the Study Area.	It is likely that a species inhabits or utilises habitat within the Study Area.
Moderate	Potential habitat for a species occurs on the site. Adequate field survey would determine if there is a 'high' or 'low' likelihood of occurrence for the species within the Study Area.	Potential habitat for a species occurs on the site and the species may occasionally utilise that habitat. Species unlikely to be wholly dependent on the habitat present within the Study Area.
Low	It is unlikely that the species inhabits the Study Area.	It is unlikely that the species inhabits the Study Area. If present at the site the species would likely be a transient visitor. The site contains only very common habitat for this species which the species would not rely on for its on-going local existence.
None	The habitat within the Study Area is unsuitable for the species.	The habitat within the Study Area is unsuitable for the species.

2.4 Field Survey

A field survey was undertaken on 15 November 2018 by two ecologists from Niche concentrating on the three flood mitigation options. The area subject to the Bends Culverts 'sediment removal' option was not surveyed, as this area of disturbance was not known at the time of the survey.

The purpose of the field survey was to validate the existing vegetation mapping, and complete a fauna habitat assessment associated with the optional sites.

No floristic plots were collected during the field survey, rather key flora and stratum characteristics were collected across each of the options to verify the vegetation mapping.

The fauna habitat assessment involved noting the presence and relative abundance of key habitat features (e.g. tree hollows, large logs, exfoliating rock, flowering resources, aquatic features) at each option.

Detailed hollow-bearing tree mapping was not undertaken as part of this assessment, rather the mapping of hollow-bearing trees by GHD (2018) was utilised where relevant.

2.5 Assessments of Significance

Formal Assessments of Significance under both the BC Act and *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) would be required when completing a Biodiversity Impact Assessment for the Project (section 5). Should a significant impact be likely, then it would trigger the requirements for a Species Impact Statement (SIS), and subsequent biodiversity offsetting. Alternatively, Council may choose to ‘opt into’ the BOS.

No Assessments of Significance have been completing as part of this assessment, however a discussion around the likelihood for a significant impact based on the threatened entities being impacted has been discussed in section 5.1.

2.6 Biodiversity offsetting

It is unclear at this stage if the project would trigger the BOS, and thus require the retirement of biodiversity credits as per the requirements of the BC Act and associated regulations and guidelines. The need to offset the project would be determined upon completion of the Assessments of Significance as described above.

To assist in the financial feasibility associated with each option, the indicative biodiversity credits and associated offsetting costs have been provided for each options in section 5.2.

2.7 Limitations

A limited set of survey methods have been employed in this investigation, however the GHD (2018) survey data has been used where relevant to guide the likelihood for impacts.

Numerous threatened plant and animal species are cryptic or difficult to detect. For instance, some cryptic plant species are more easily detected at certain times of the year, such as during flowering events. Some fauna can only be detected during certain seasons (e.g. migration patterns or intra-torpor periods).

Given the full extent of the mitigation works are not yet known, it is difficult to ascertain the indirect impacts associated with the project. This preliminary assessment has therefore focused on the known direct impact areas provided to Niche by Royal Haskoning DHV.

3. Results

3.1 Existing Environment

3.1.1 Plant Community Types

The Study Area and surrounds have been mapped previously by GHD (2018) and Smith and Smith (2009). The field survey completed as part of this assessment aimed at confirming the validated vegetation mapping associated with the three options.

The field survey confirmed that the GHD (2018) and Smith and Smith (2009) vegetation mapping was broadly accurately, within only some minor amendments made to areas of exotic weeds and regenerating PCT 1794 - Bangalay - Smooth-barked Apple / She-oak open forest on sandy alluvium in coastal parts of the Sydney Basin.

Based on the vegetation mapping, seven Plant Community Types (PTCs) were recorded within Study Area. Descriptions associated with each of the PCTs (as described by GHD (2018)) associated with each of the three options, including the one 'sediment removal option' have been provided in Table 3.

Table 3: Plant Community Types

Vegetation community	Description based on site inspection and GHD (2018)	Threatened Ecological Community		Mapped occurrence in the Study Area		
			The Bends Culverts	The Bends Culverts – 'sediment removal option'	Sports Centre	Oxford Falls
PCT 1794 - Bangalay - Smooth-barked Apple / She-oak open forest on sandy alluvium in coastal parts of the Sydney Basin	Over storey: The most common canopy species is Bangalay (*Eucalyptus botryoides*) with occasional occurrences of Blue Gums (*Eucalyptus saligna/E. botryoides* hybrid), Swamp Mahogany (*E. robusta*) and Smooth Barked Apple (*Angophora costata).* Mid storey: The mid-storey includes patches of exotic shrub species, especially Privet (*Ligustrum lucidum* and *Ligustrum sinense*) and Lantana (*Lantana camara*), although there are also extensive patches of native species, including Brush Daphne (*Pittosporum undulatum*), Smooth Cheese-tree (*Glochidion ferdinandi* var. *ferdinandi*), Coast Banksia (*Banksia integrifolia* subsp. *integrifolia*), Paperbarks (*Melaleuca* spp.), Tea tree (*Leptospermum* spp.) and Swamp Oak (*Casuarina glauca*). Groundcover: Groundcover vegetation is generally dense and includes sedges such as Tassel Cord Rush (*Baloskion tetraphyllus*), Saw Sedges (*Gahnia* spp.) and Spiny-headed Mat-rush (*Lomandra longifolia)*; ferns, especially Bracken (*Pteridium esculentum*) and Rainbow Fern (*Calochlaena dubia*); grasses such as Wiry Panic (*Entolasia stricta*), Weeping Grass (*Microlaeana stipoides* var. *stipoides*) and Blady Grass (*Imperata cylindrica*); and herbs, including Whiteroot (*Pratia purpurascens*) and Scurvy Weed (*Commelina cyanea*).	Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South-east Corner Bioregions	0.02	0.00	0.00	0.00
PCT 659 - Bangalay - Old-man Banksia open forest on coastal sands, Sydney Basin Bioregion and South East Corner Bioregion	[1]Over storey likely dominated by Blackbutt (*Eucalyptus pilularis)*, Old Man Banksia (*Banksia serrata*), Coastal Banksia (*Banksia integrifolia* subsp. *integrifolia)*, Cheese Tree (*Glochidion ferdinandi*).	Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney	0.00	2.77	0.00	0.00

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[1] No validated vegetation mapping was undertaken within this PCT as details of the direct disturbance were not known at the time of survey. As such, existing vegetation mapping has been utilised, and PCT descriptions are based-off the OEH (2019d) Vegetation Information System database.

Vegetation community	Description based on site inspection and GHD (2018)	Threatened Ecological Community		Mapped occurrence in the Study Area		
			The Bends Culverts	**The Bends Culverts – 'sediment removal option'**	**Sports Centre**	**Oxford Falls**
	Ground cover likely dominated by Blue flax-lily (*Dianella caerulea*), Purple Coral Pea (*Hardenbergia violacea*), Matt Rush (*Lomandra longifolia*), Pomax (*Pomax umbellata*).	Basin and South-east Corner Bioregions				
PCT 1234 - Swamp Oak swamp forest fringing estuaries	Over Storey: Most patches consist of monotypic stands of Swamp Oak (*Casuarina glauca*), with a sparse to dense groundcover of grasses, sedges and forbs. Mid Storey: n/a Groundcover: Common groundcover species include Common Reed (*Phragmites australis*), New Zealand Spinach (*Tetragonia tetragonioides*), Bare Twig-rush (*Baumea juncea*), Couch (*Cynodon dactylon*) and Nioaka (*Sporobolus virginicus* var. *minor*).	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions.	0.15	0.00	0.74	0.00
PCT 1841: Smooth-barked – Apple – Turpentine – Blackbutt tall open forest	Over storey: Common canopy species include Smooth-barked Apple, Turpentine (*Syncarpia glomulifera* subsp. *glomulifera*), Blackbutt (*Eucalyptus pilularis*), Sydney Blue Gum and hybrids (*Eucalyptus saligna* and *E. saligna/E. botryoides* hybrid). Mid storey: Mid-storey species include Forest Oak (*Allocasuarina torulosa*), Murrogun (*Myrsine variabilis*), Brush Daphne (*Pittosporum undulatum*), Blueberry Ash (*Elaeocarpus reticulatus*) and Elderberry Panax (*Polyscias sambucifolia*). Common vine species include Five-leaf water Vine (*Cissus hypoglauca),* Sweet Sarsparilla (*Smilax glyciphylla)* and Wonga Vine (*Pandorea pandorana* var. *pandorana)*. Groundcover: Ferns, especially Bracken and False Bracken form dense patches of ground cover.	Not listed	0.01	0.05	0.00	0.00
PCT 781 - Coastal freshwater lagoons of the Sydney	Over Story: n/a Mid Storey: n/a	Freshwater Wetlands on	0.04	0.06	0.04	0.00

Vegetation community	Description based on site inspection and GHD (2018)	Threatened Ecological Community		Mapped occurrence in the Study Area		
			The Bends Culverts	The Bends Culverts – 'sediment removal option'	Sports Centre	Oxford Falls
Basin Bioregion and South East Corner Bioregion	Groundcover: The floristics and structure of the Freshwater Wetland patches vary, although common wetland species in most patches include Cumbungi (*Typha orientalis*) and Common Reed (*Phragmites australis*). Grasses and sedges include Water Couch (*Paspalum distichum*) Twig-rush (*Baumea* spp.), Spike-rush (*Eleocharis* spp.) and Rush (*Juncus* species). Common herbs include Water Pepper (*Persicaria* spp.) and Woolly Frogmouth (*Philydrum lanuginosum*).	Coastal Floodplains				
PCT 1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies	Dominant species include the following: Old Man Banksia (*Banksia serrata),* Blackbutt (*Eucalyptus piperita), Coastal Red Gum (Angophora costata),* Red Bloodwood (*Corymbia gummifera), Christmas Bush (Ceratopetalum gummiferum), Geebung (Persoonia levis),* Jelly Bush (*Leptospermum polygalifolium),* Crinkle Bush (*Lomatia silaifolia);* Heath-leaved Banksia (*Banksia ericifolia);* Sunshine Wattle (*Acacia terminalis).*	Not listed	0.00	0.00	0.00	0.07
Non-native	Predominant species Privet (*Ligustrum lucidum and Ligustrum sinense*) and Lantana (*Lantana camara*).	Not listed	0.05	0.56	0.26	0.00
Total		-	**0.27**	**3.44**	**1.04**	**0.07**

3.1.2 Threatened Ecological Communities

Three of the PCTs recorded within the Study Area are consistent with Threatened Ecological Communities (TECs) listed under the BC Act and/or EPBC Act. The area of each TECs associated with each option is provided in Table 4.

Table 4: TECs in the Study Area

Threatened ecological Community	**BC Act**	**EPBC Act**	**Area and condition of TEC in the Study Area**			
			The Bends Culverts	**The Bends Culverts – 'sediment removal option'**	**Sports Centre**	**Oxford Falls**
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South-east Corner Bioregions	Listed	Not listed	Area: 0.02 ha Condition: predominantly moderate condition throughout impact site, however exposed to direct impacts from localised flooding from Middle Creek and edge effects from the Wakehurst Parkway. Poorer condition patches occur closer to the roads edge and contain localised and dense weed infestations of Privet (*Ligustrum lucidum* and *Ligustrum sinense*) and Lantana (*Lantana camara*).	Area 2.77 ha Condition: predominantly moderate condition throughout impact site. Patches of Privet (*Ligustrum lucidum* and *L sinense*) and Lantana (*Lantana camara*).	Not mapped within direct disturbance area	Not mapped within direct disturbance area
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions.	Listed	Listed	Area 0.15 ha Condition: This vegetation type is in moderate/good condition throughout impact site. Small infestation of Privet (*Ligustrum lucidum* and *Ligustrum sinense*) and Lantana (*Lantana camara*) along creekline	-	Area: 0.74 ha Condition: This vegetation type is in moderate/good condition throughout impact site. Small infestation of Privet (*Ligustrum lucidum* and *Ligustrum sinense*) and Lantana (*Lantana camara*) along creekline	Not mapped within direct disturbance area
Freshwater Wetlands on Coastal Floodplains	Listed	Not listed	Area: 0.04 ha Condition: This vegetation type is moderate/good throughout impact area. Small infestation of Privet (*Ligustrum lucidum*	Area: 0.06 ha Condition: This vegetation type is moderate/good throughout impact	Area: 0.04 ha Condition: This vegetation type is moderate/good throughout	n/a

Threatened ecological Community	**BC Act**	**EPBC Act**	**Area and condition of TEC in the Study Area**			
			The Bends Culverts	**The Bends Culverts – ‘sediment removal option’**	**Sports Centre**	**Oxford Falls**
			and *Ligustrum sinense*) and Lantana (*Lantana camara*) along creekline	area. Small infestation of Privet (*Ligustrum lucidum* and *Ligustrum sinense*) and Lantana (*Lantana camara*) along creekline	impact area. Small infestation of Privet (*Ligustrum lucidum* and *Ligustrum sinense*) and Lantana (*Lantana camara*) along creekline	

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Wakehurst Parkway Flood Mitigation - Ecological Assessment

Sports Complex

Niche PM: MR
Niche Proj. #: 4604
Client: Northern Beaches Council

Figure 2

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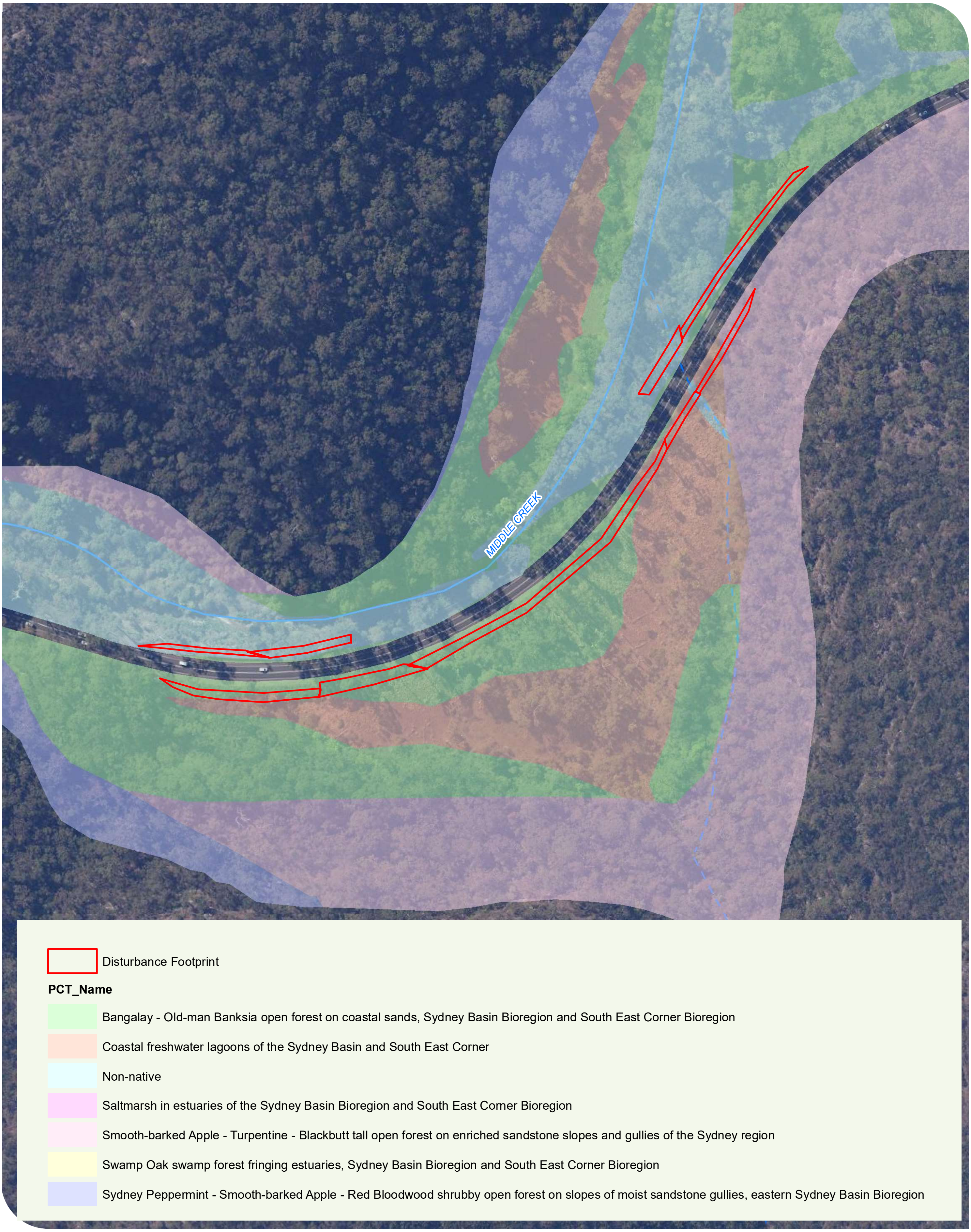

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Wakehurst Parkway Flood Mitigation - Ecological Assessment

The Bends Culverts

Niche PM: MR
Niche Proj. #: 4604
Client: Northern Beaches Council

Figure 3

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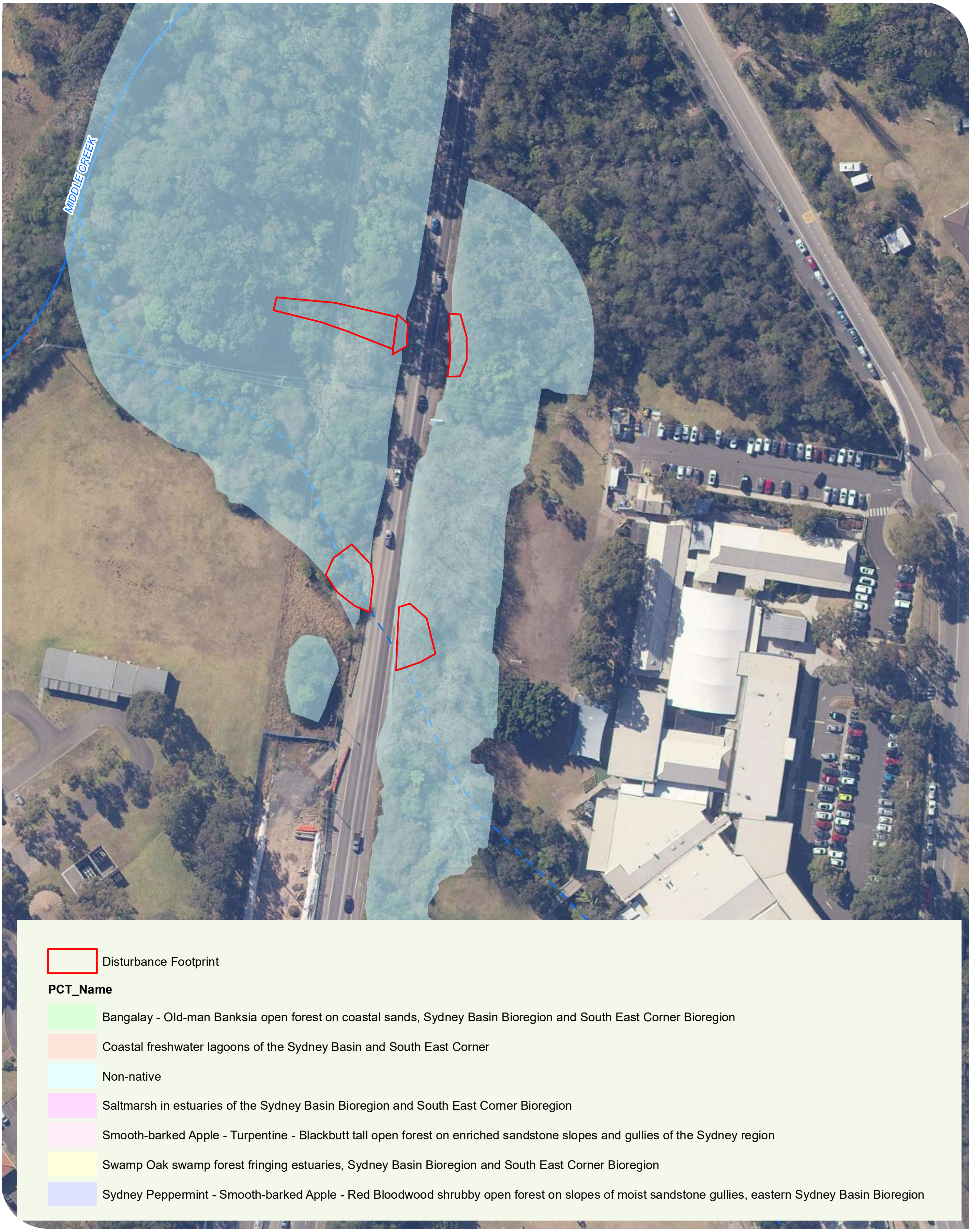

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Wakehurst Parkway Flood Mitigation - Ecological Assessment

Oxford

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Niche Proj. #: 4604
Client: Northern Beaches Council

Figure 4

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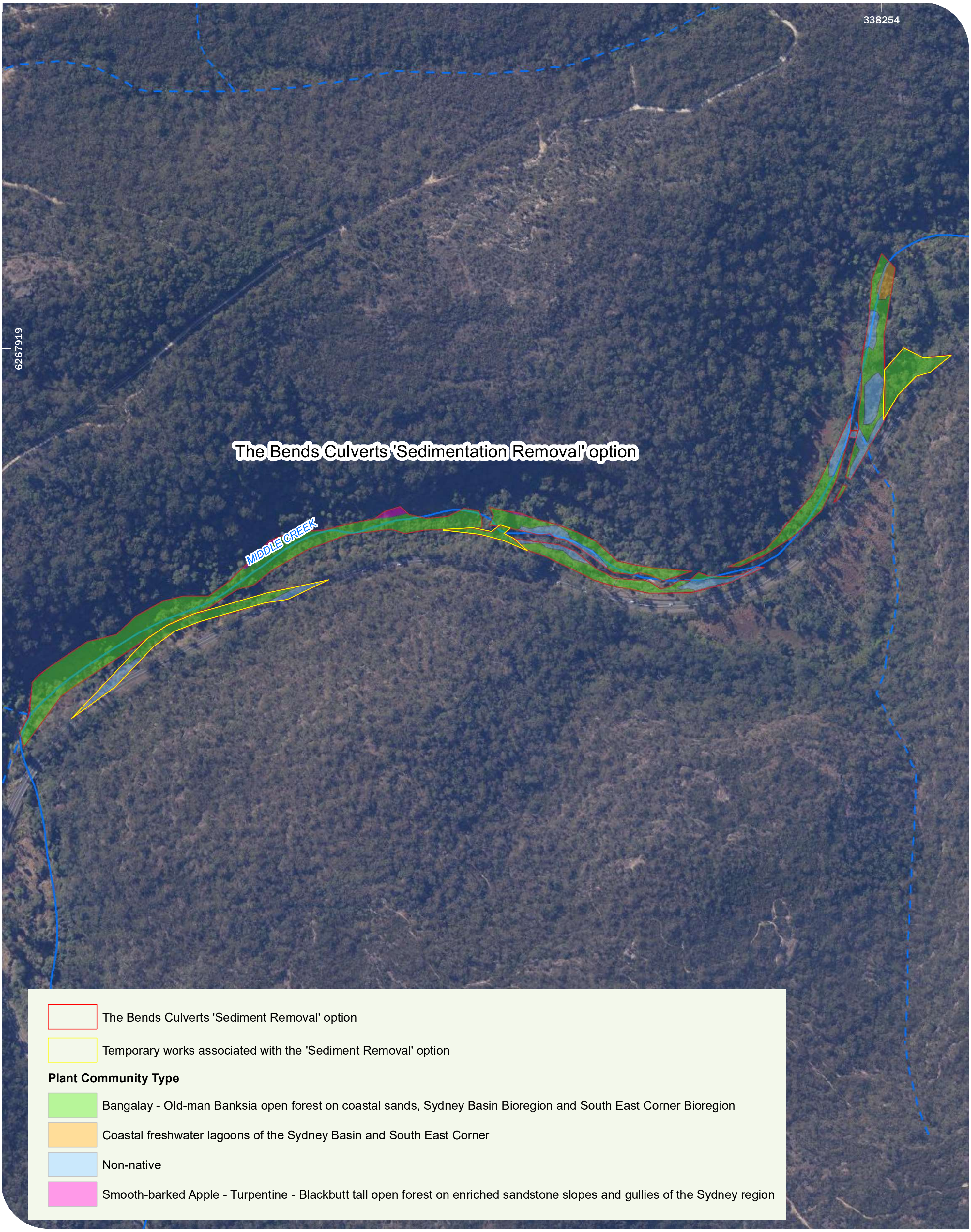

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Wakehurst Parkway Flood Mitigation - Ecological Assessment

The Bends Culverts 'sediment removal' option

Niche PM: MR
Niche Proj. #: 4604
Client: Northern Beaches Council

Figure 5

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3.1.3 Threatened Flora

A total of 37 threatened flora listed on the BC and/or EPBC Act were identified as subject species in this assessment (Appendix 1).

No threatened species were recorded during field survey, nor have any been recorded by GHD (2018). Given there is marginal habitat present within the area of direct disturbance, all potentially occurring threatened species were considered to have a 'low' or 'no' likelihood of occurrence which is a similar conclusion to that provided in GHD (2018). However, it should be noted that since indirect impacts are not known at this stage, targeted threatened flora surveys are likely to be required once details are known, and incorporated into the impact assessment. In particular, threatened flora surveys may be required for those species reliant upon riparian habitats, including: *Callistemon linearifolius, Deyeuxia appressa, Grevillea shiressii, Triplarina imbricata, Haloragodendron lucasii, Leptospermum deanei, Melaleuca biconvexa* and *Persoonia mollis subsp. maxima.*

3.1.4 Fauna habitat

Based on the results of the field survey and previous assessments, a list of fauna habitats located at each of the optional impact sites are listed below in Table 5.

Table 5: Fauna habitats within proposed impact areas

Fauna Habitats	Description	Occurrence in the Study Area			
		The Bends Culverts	The Bends Culverts – 'sediment removal option'	Sports Centre	Oxford Falls
Tree Hollows	Trees which contain hollows are particularly important for those species of animals, including many threatened species, which specifically require such hollows for shelter and nesting. These animals are termed 'hollow-dependent' in that they require hollows as a key component of their habitat either on a daily or seasonal basis.	Present	Likely	Present	Not present
Logs	Fallen logs instantly provide complex structures where a diverse range of organisms can find stable microclimates for nesting, denning, feeding, and food storage. From microscopic protozoa and magnificent mushrooms, to birds and amphibians	Present	Likely	Present	Present
Surface Rock	Sandstone outcrops also provide shelter habitat for a range of reptiles and roosting habitat for microbats. A range of overhangs, under hangs cracks and fissures were observed within sandstone outcrops.	Not present or very minor	Likely to be present	Not present or very minor	Not present or very minor
Aquatic Habitat Features	Freshwater wetland areas are densely vegetated with native wetland and aquatic plants. These include a variety of sedges and rushes including Plume Rush (*Baloskion tetraphyllum* subsp. *meiostachyum*), Jointed Twig-rush (*Baumea articulata*), Broad-leaved Cumbungi (*Typha orientalis*) or *Baumea juncea*. Wetlands in the Study Area were inundated with water at the time of the survey and would contain standing water periodically throughout the year.	Present			

Fauna Habitats	Description	Occurrence in the Study Area			
		The Bends Culverts	The Bends Culverts – 'sediment removal option'	Sports Centre	Oxford Falls
	These freshwater wetlands provide high value basking and refuge habitat for a range of frog species.				

3.1.5 Threatened fauna

No threatened or migratory fauna were recorded in the Study Area during the field survey, however it should be noted that targeted surveys were not conducted as part of the field survey.

A total of 65 threatened or migratory fauna listed on the BC and/or EPBC Act were identified as subject species in this assessment (Appendix 1). This list was derived from the database searches outlined in Section 2.1.

Using the results of the field survey, GHD (2018) survey results, and analysis of habitat preferences, of this list of subject species, 16 species were considered to have a 'Moderate' or greater likelihood of occurrence to occur within the Study Area (Appendix 1) mainly due to the use of the sites as foraging habitat. Species with a moderate to high likelihood of occurrence include those species in Table 6. Of the options proposed, the Oxford Falls site contains the least habitat potential for threatened fauna, whilst the Bends Culverts sediment removal option contains potential habitat for the most threatened fauna species.

Table 6. Threatened fauna with a moderate to high likelihood of occurrence within Study Area

Scientific Name	Common Name	Threatened listing[2]		Options				Habitat descriptions based on field survey and GHD (2018) records
		BC Act	EPBC Act	The Bends Culverts	The Bends Culverts ‘sediment removal’ option	Sport Centre	Oxford Falls	
Pseudophryne australis	Red-crowned Toadlet	V	-	High	High	High	Low	Recorded by GHD (2018) further along Middle Creek immediately east of the ‘Bends Culvert’. The area of disturbance occurs outside the species polygon (breeding habitat) mapped by GHD, however potential foraging habitat may be impacted by the project.
Pandion cristatus	Eastern Osprey	V	M	High	High	High	Low	Recorded by GHD (2018) further along Middle Creek immediately east of the ‘Bends Culvert’. The area of disturbance occurs outside the species polygon (breeding habitat) mapped by GHD, however potential foraging habitat may be impacted by the project.
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	-	High	High	High	Low	Recorded by GHD (2018) immediately outside the disturbance footprint. Approximately 2.3 ha of foraging habitat may be impacted.
Daphoenositta chrysoptera	Varied Sittella	V	-	High	High	High	High	Highly likely to utilise the habitat of each option give the wide range of habitat types the species can occupy.
Ixobrychus flavicollis	Black Bittern	V	-	Moderate	High	High	Low	Recorded by GHD (2018) further along Middle Creek immediately east of the ‘Bends Culvert’. The area of disturbance occurs outside the species polygon (breeding habitat) mapped by GHD, however potential foraging habitat may be impacted by the project.
Ninox strenua	Powerful Owl	V	-	High	High	High	Low	Recorded by GHD (2018) further along Middle Creek immediately east of the ‘Bends Culvert’. The area of disturbance occurs outside the species polygon (breeding habitat) mapped by GHD, however potential foraging habitat may be impacted by the project.
Tyto tenebricosa	Sooty Owl	V	-	Moderate	Moderate	Moderate	Low	Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost tree unlikely.

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[2] V = Vulnerable; E = Endangered; M = Migratory

Scientific Name	Common Name	Threatened listing[2]		Options				Habitat descriptions based on field survey and GHD (2018) records
		BC Act	EPBC Act	The Bends Culverts	The Bends Culverts 'sediment removal' option	Sport Centre	Oxford Falls	
Miniopterus australis	Little Bentwing-bat	V	-	Moderate	Moderate	Moderate	Moderate	Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost tree unlikely.
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V	-	Moderate	Moderate	Moderate	Moderate	Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost tree unlikely.
Mormopterus norfolkensis	Eastern Freetail-bat	V	-	Moderate	Moderate	Moderate	Moderate	Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost tree unlikely.
Myotis macropus	Southern Myotis	V	-	Moderate	Moderate	Moderate	Moderate	Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost trees unlikely, however foraging habitat is likely.
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	-	Moderate	Moderate	Moderate	Moderate	Species can utilise a range of habitat types up to 12km from roost site. Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost trees unlikely, however foraging habitat is likely.
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	High	High	High	High	No camp sites known in the disturbance area. Foraging habitat would be impacted.
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Moderate	Moderate	Moderate	Moderate	Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost trees unlikely, however foraging habitat is likely.
Scoteanax rueppellii	Greater-Broad Nosed Bat	V	V	Moderate	Moderate	Moderate	Moderate	Potential foraging habitat to be impacted. No hollow-bearing trees mapped by GHD (2018) occur in the disturbance footprint so removal of roost tree unlikely.
Heleioporus australiacus	Giant Burrowing Frog	V	V	Low	Moderate	Low	Low	GHD (2018) notes that potential habitat for the Giant Burrowing Frog may occur within the disturbance area. Further field survey would be required to confirm the presence of the species and the extent of habitat (if any) within the disturbance areas and surrounds. As a conservative approach we have assumed approximately 2.41 ha of Giant Burrowing Frog habitat would be impacted by the Project.

4. Potential impacts

4.1 Potential impacts

An assessment of the potential impacts of the project on biodiversity is provided in Table 6. Impacts are categorised as direct or indirect as described in DECC (2007), which states:

> *“**Direct impacts** are those that directly affect the habitat and individuals. They include, but are not limited to, death through predation, trampling, poisoning of the animal/plant itself and the removal of suitable habitat. When applying each factor, consideration must be given to all of the likely direct impacts of the proposed activity or development.*
>
> ***Indirect impacts** occur when project-related activities affect species, populations or ecological communities in a manner other than direct loss. Indirect impacts can include loss of individuals through starvation, exposure, predation by domestic and/or feral animals, loss of breeding opportunities, loss of shade/shelter, deleterious hydrological changes, increased soil salinity, erosion, inhibition of nitrogen fixation, weed invasion, fertiliser drift, or increased human activity within or directly adjacent to sensitive habitat areas. As with direct impacts, consideration must be given, when applying each factor, to all of the likely indirect impacts of the proposed activity or development.”*

A likelihood rating of known, High, Moderate or Low has been assigned to each of the potential impacts listed in Table 6 which illustrates that the project would likely result in a number of unavoidable direct impacts and potential indirect impacts. However it should be noted, that the area of indirect impacts are not yet known given the full extent of the works have not been provided to Niche.

Table 7. Summary of impacts

Impact	**Extent of impact as a result of the project**			
Direct impacts	**The Bends Culverts**	**The Bends Culverts**	**Sports Centre**	**Oxley Falls**
Removal or modification of native vegetation	**Known:** 0.21 ha	**Known:** 2.88 ha	**Known:** 0.77 ha	**Known:** 0.07 ha
Loss of individuals of a threatened flora	**Unlikely:** Based on the result of the current field survey and GHD (2018), no threatened flora would be removed as part of the project.			
Loss of threatened fauna habitat	**Known:** All options would impact upon habitat for threatened fauna.			
Removal or modification of threatened species habitat other than native vegetation (micro-habitat features)	**Moderate:** the area to be impacted does contain tree hollows or other important habitat features which may be used by threatened species.			

<table>
<tr><th>Impact</th><th colspan="4">Extent of impact as a result of the project</th></tr>
<tr><td>Death through trampling</td><td colspan="4">Low: impact area is a strip of vegetation along Wakehurst Parkway. Any death to native vegetation and habitat would be considered as part of the area of direct impact.</td></tr>
<tr><td>Death through poisoning</td><td colspan="4">Low: no poisons are proposed to be used as part of the project. Harmful substances used in construction would all be controlled as per required Australian Standards.</td></tr>
<tr><td>Modification to waterways</td><td colspan="4">Known: Flood mitigation works would impact upon existing waterways.</td></tr>
<tr><td>Fragmentation</td><td colspan="4">Moderate: the removal of vegetation in the Study Area could exacerbate fragmentation in the local area along the road.</td></tr>
<tr><td colspan="5">Indirect impacts</td></tr>
<tr><td>Predation by domestic and/or feral animals</td><td colspan="4">Low: the project is not likely to increase the presence of domestic or feral animals in the local area.</td></tr>
<tr><td>Loss of shade/shelter</td><td colspan="4">Known: the removal of vegetation in the Study Area would result in a significant loss of shade/shelter for local fauna.</td></tr>
<tr><td>Loss of breeding opportunities</td><td>High: There are a few trees to be removed contain hollows. Vegetation may be suitable for breeding by nest building birds.</td><td>High: There are likely to be pools suitable for breeding amphibians that would be impacted by the sedimentation removal.</td><td>Moderate: There are a few trees to be removed contain hollows. Vegetation may be suitable for breeding by nest building birds.</td><td>Low: the trees to be removed do not contain hollows, however vegetation within the Study Area may be suitable for breeding by nest building birds.</td></tr>
<tr><td>Loss of individuals through starvation</td><td colspan="4">Low: the habitat to be removed in the Study Area occurs as a strip of vegetation along Wakehurst Parkway. Extensive areas of habitat nearby would not be impacted by the project. Foraging habitat for fauna would remain in abundance in the locality.</td></tr>
<tr><td>Loss of individuals through exposure</td><td colspan="4">Low: habitat to be removed in the impact area is a corridor alongside Wakehurst Parkway. Extensive areas of habitat nearby would not be impacted by the project. Shelter habitat for fauna would remain in abundance in the locality.</td></tr>
<tr><td>Deleterious hydrological changes</td><td colspan="4">Low: the project is unlikely to cause greater than negligible alterations to existing flow regimes or result in un-contained nutrient-laden sedimentation. A sediment control and erosion plan would be recommended to lessen potential impacts during construction on nearby receiving environments.</td></tr>
<tr><td>Increased soil salinity</td><td colspan="4">Low: the project is not likely to alter the soil salinity of the Study Area or surrounding areas.</td></tr>
<tr><td>Sedimentation and erosion</td><td colspan="4">Moderate: Safeguards are recommended to ensure sediments are contained during and post construction.</td></tr>
<tr><td>Inhibition of nitrogen fixation</td><td colspan="4">Low: unlikely to be greater than current impact.</td></tr>
<tr><td>Weed invasion</td><td colspan="4">Low: unlikely to be greater than current impact. Controls regarding clearing of weeds recommended.</td></tr>
<tr><td>Fertiliser drift</td><td colspan="4">Low: no fertilisers to be used as part of the project.</td></tr>
</table>

Impact	Extent of impact as a result of the project
Increased human activity within or directly adjacent to sensitive habitat areas	**Low:** unlikely to be greater than current impact along Wakehurst Parkway.

4.2 Affected threatened ecological communities

As discussed in Section 3.1.2, three TECs are associated with the PCTs recorded within the Study Area.

As shown in Table 7 the following conclusions can be made:

- The Bends Culverts 'sediment removal option' would result in the greatest area of direct impact. The 'sediment removal option' would result in direct impact to two TECs (Swamp Sclerophyll Forest, and Freshwater Wetlands) totalling an area of 2.83 hectares.
- The Bends Culverts optional site would result in a direct impact to three TECs (Swamp Sclerophyll Forest, Swamp Oak Floodplain Forest and Freshwater Wetlands), totalling an area of 0.21 hectares of direct impact.
- The Sports Centre optional site would result in an impact to two TECs (Swamp Oak Floodplain Forest, and Freshwater Wetlands) totalling approximately 0.78 hectares of direct impact.
- The Oxford optional site would not impact any TECs.

Assessments of significance under the BC Act and/or EPBC Act would need to be completed for all impacts to TECs, and must take into consideration indirect impacts, which would likely increase the areas proposed in Table 7.

Table 8. Direct impacts to TECs

Site	Area of Threatened Ecological Community to be impacted (ha)			Total Area (ha)
	Swamp Sclerophyll Forest on Coastal Floodplains	Swamp Oak Floodplain Forest	Freshwater Wetlands on Coastal Floodplains	
The Bends Culverts	0.02	0.15	0.04	0.21
The Bends Culvert 'sediment removal' option	2.77	0.00	0.06	2.83
Sports Centres	0.00	0.74	0.04	0.78
Oxford Falls	0.00	0.00	0.00	0.00

4.3 Affected flora

No threatened flora were identified during the field survey although no targeted surveys were conducted. GHD (2018) did not record any threatened species during their survey, and there are no previous records in the Study Area.

However, as discussed in section 2.7, it should be noted that this assessment has only considered the area of direct impacts provide to Niche. Should indirect impacts from the operations result in a greater area of impact than that considered and surveyed by GHD (2018), then further consideration would need to be attributed to the following species that can occur adjacent to riparian habitats: *Callistemon linearifolius, Deyeuxia appressa, Grevillea shiressii, Triplarina imbricata, Haloragodendron lucasii, Leptospermum deanei, Melaleuca biconvexa* and *Persoonia mollis subsp. Maxima.*

4.4 Affected fauna

Fauna habitats occurring in the Study Area may provide shelter, foraging and breeding habitat to the threatened/migratory fauna listed in section 3.1.5.

Without knowing the precise details of the operations, it is difficult to gauge the impact to threatened fauna. However, assuming the Study Area would be directly cleared, the flood mitigation can impact upon fauna in a number of ways with the significance of an impact greatest if any of the following situations occur:

- Death or injury of individuals.
- Loss or disturbance of limiting foraging resources.
- Loss or disturbance of limiting breeding resources.

Limiting resources are those that are important for a particular species survival. For example, fauna that only feed on certain types of plants or breed in certain habitats such as deep water pools in flowing creeks.

The assessment of affected threatened fauna in section 3.1.5 concluded that 15 threatened fauna have a moderate or greater potential to be negatively impacted by the proposal:

- Red-crowned Toadlet
- Giant Burrowing Frog
- Eastern Osprey
- Glossy Black-Cockatoo
- Varied Sittella
- Black Bittern
- Powerful Owl
- Sooty Owl
- Little Bentwing-bat
- Eastern Bentwing-bat
- Eastern Freetail-bat
- Southern Myotis
- Grey-headed Flying-fox
- Large-eared Pied Bat
- Rufous Fantail (migratory under EPBC).

Assessments of significance (BC Act) and/or significant impact criteria assessments (EPBC Act) would need to be completed for these threatened fauna depending on the option, in order to determine the significance of impacts to limiting habitat features.

5. Recommendations

5.1 Biodiversity Impact Assessment

A biodiversity impact assessment using the OEH (2017) Biodiversity Assessment Methodology (BAM) would be required for each of the three options and the 'Bends Culvert sediment removal option'. The impact assessment would be assessed under the requirements of the *Environmental Planning and Assessment Act 1979* (EP&A Act), associated BC Act and *NSW Biodiversity Conservation Regulation 2017* (BC Regulation 2017), which provides proponents with two options for impact assessment and offsetting:

1. Preparation of a biodiversity impact assessment that applies assessments of significance (five-part test) under the BC Act to determine whether significant impacts on threatened biodiversity are likely. If a significant impact is considered unlikely there may be no further requirement for ecological assessment or any offset requirement. If a significant impact is likely, then a Species Impact Statement (SIS) and subsequent offsetting would be required.
2. Use of the Biodiversity Offset Scheme (BOS) and BAM to prepare a Biodiversity Development Assessment Report (BDAR) under the BC Act. The BDAR would outline avoidance and mitigation measures as well as offset requirements for all vegetation clearing regardless of whether significant impacts on threatened biodiversity were likely to occur. Project approval would then require offsetting as per the requirements of the BDAR or to a lesser degree as agreed upon after consultation with the Minister administering the BC Act.

Council may consider the first option listed above to test the significance of the impacts for each of the threatened entities associated with each optional site. This would be a cheaper alternative than progressing immediately with the second option described above given the cost of biodiversity offsetting.

The impact assessment would also need to consider impacts to threatened biodiversity listed on the EPBC Act.

5.2 Conservation/offsetting

It is unclear if biodiversity offsetting would be required, as no Assessments of Significance have been completed as part of this assessment. However, it seems likely that based on the area of direct impact associated with the 'Bends Culvert sediment removal option', significant impacts are likely due to the following:

- Removal of approximately 2.77 ha of Swamp Sclerophyll Forest TEC.
- Removal of 2.88 ha of fauna habitat, in particular threatened fauna that would require the retirement of 'species fauna credits' if offsetting is required. Species credit fauna include: Red-crowned Toadlet, Giant Burrowing Frog habitat (note this needs to be confirmed via targeted survey), Southern Myotis and of Large-eared Pied Bat.

The Bends Culverts and Sports Complex options have biodiversity impacts that may result in a significant impact, especially once indirect impacts are determined and added to the overall project impact. A summary of the impacts for the Bends Culvert and the Sports Complex includes the following:

Bends Culverts option:

- Impacts to approximately 0.15 ha of Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions TEC.
- Impacts to approximately 0.04 ha of Freshwater Wetlands on Coastal Floodplains TEC.

- Impacts to approximately 0.02 ha of Swamp Sclerophyll Forest TEC
- Impacts to approximately 0.22 ha of Red-crowned Toadlet habitat
- Impacted to approximately 0.22 ha of Powerful owl foraging habitat
- Impacts to approximately 0.22 ha of Bitter habitat.

Sports Complex option:

- Impacts to approximately 0.74 ha of Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions TEC.
- Impacts to approximately 0.04 ha of Freshwater Wetlands on Coastal Floodplains TEC.
- Impacts to approximately 0.78 ha of Red-crowned Toadet habitat
- Impacted to approximately 0.78 ha of Powerful owl foraging habitat
- Impacts to approximately 0.78 ha of Bitter habitat.

The Oxford option, seems less likely to result in a significant impact given the relatively minor impacts to biodiversity values:

- Only 0.07 ha of native vegetation and habitat would be direct impacted.
- It is unlikely that any TECs would be impacted.
- No Red-crowned Toadlet habitat has been mapped within the site
- No threatened flora or fauna have been recorded within the site.

Should a significant impact be likely, then it would trigger a SIS which would entail biodiversity offsetting. The BAM would be used to determine the impact assessment process, and to determine the offset in terms of biodiversity credits.

In order to provide an indication of the likely credits associated with each options should an SIS be required or if Council chose to ‘opt’ into completing a BDAR, an offsetting scenario has been provided in Table 9 for each option. The credits required has been estimated by using an average of 35 credits per hectare (with impacts less than 0.5 ha generating 5 credits), which is the average credits generated at a relatively in-tact native vegetation development site using the BAM. The cost per credit has been based on the OEH (2019) Biodiversity Conservation Trust Payment Calculator (costed at April 2019) and has also been provided in Table 9. It should be noted that the credits prices are updated quarterly, and thus should only be used as a preliminary guide. The offsetting has assumed that the only species credits required for offsetting include the Red-crowned Toadlet, Giant Burrowing Frog, Powerful Owl (due to roosting habitat), Black Bittern and Glossy Black Cockatoo. The cost for the offsetting for threatened microbats have been included for the Bends Culverts ‘sediment removal option’.

Table 9. Indicative credit costs should an SIS be required for each option

Option	Impact area (ha)	Credit estimate	Credit per credit	Total cost
The Bends Culverts option				
PCT 1794 - Bangalay - Smooth-barked Apple / She-oak open forest on sandy alluvium in coastal parts of the Sydney Basin	0.02	5	$1,616.94	$8,084.70
PCT 1234 - Swamp Oak swamp forest fringing estuaries	0.15	5	$1482.778	$7,413.89
PCT 1841: Smooth-barked – Apple – Turpentine – Blackbutt tall open forest	0.01	5	$1616.94	$8,084.70
PCT 781 - Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	0.04	5	$2377.6	$11,888.00
Red-crowned Toadlet	0.27	17	$630.47	$10,717.99
Powerful Owl	0.27	17	$630.47	$10,717.99
Black Bittern	0.27	17	$265.97	$4,521.49
Glossy Black Cockatoo	0.27	17	$265.97	$4,521.49
			Total	**$66,950.25**
Sports Complex option				
PCT 1234 - Swamp Oak swamp forest fringing estuaries	0.74	35	$1482.778	$51,897.23
PCT 781 - Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	0.04	5	$2377.6	$11,888.00
Red-crowned Toadlet	0.74	35	$630.47	$22,066.45
Powerful Owl	0.74	35	$630.47	$22,066.45
Black Bittern	0.74	35	$265.97	$9,308.95
Glossy Black Cockatoo	0.74	35	$265.97	$9,308.95
			Total	**$126,536.02**
Oxford option				
PCT 1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies	0.07	5	$ 2297.16	$11,485.80
			Total	**$11,485.80**
The Bends Culverts sediment removal option				
PCT659 Bangalay - Old-man Banksia open forest on coastal	2.77	97	$4,169.49	$404,440.53

Option	Impact area (ha)	Credit estimate	Credit per credit	Total cost
sands, Sydney Basin Bioregion and South East Corner Bioregion				
PCT781 Coastal freshwater lagoons of the Sydney Basin and South East Corner	0.06	2	$6,622.52	$13,245.04
PCT1841 Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	0.05	2	$18,345.03	$36,690.05
Red-crowned Toadlet	2.41	72	$630.47	$45,394.17
Giant Burrowing Frog	2.41	72	$265.97	$19,149.72
Southern Myotis	2.41	72	$1,062.33	$76,488.11
Large-eared Pied Bat	2.41	72	$1,062.33	$76,488.11
			Total	**$671,985.73**

5.3 Referral

Referral of a project is recommended if there is likely to be a significant impact on a matter of national environmental significance (MNES) listed under the EPBC Act, such as threatened species or communities, or if there is uncertainty over whether the impact will be significant or not.

Based on current information, the Bends Culverts ‘sediment removal option’, the Bends Culverts, and Sports Centre options have the potential to have an impact on Coastal Swamp Oak Forest of New South Wales and South East Queensland ecological community, which is listed as a TEC on the EPBC Act. A number of threatened fauna species listed on the EPBC Act, including the Giant Burrowing Frog, Large-eared Pied Bat, Greater-Broad Nosed Bat, Grey-headed Flying Fox and Eastern Osprey, also have the potential to be impacted by the Project.

It is unclear if a significant impact is likely given the details around indirect impacts are not yet known. However, should a significant impact by likely, EPBC Act offsets would be required for any MNES that is likely to be significantly impacted by a proposal. The Commonwealth has its own offset policy and offsets calculator, and would require a ‘land-based biodiversity offset’. To date, the Department of Environment and Energy (DPEE) will not accept a proponent paying into the Biodiversity Conservation Trust Fund as a suitable offset mechanism for significant impacts to a MNES.

Early referral of a proposal that is likely to significantly impact MNES is recommended so that if the Minister for the Environment determines the project to be a controlled action, any additional survey requirements can be incorporated into the field season and minimise further remobilisation of field staff.

6. Conclusion

This assessment has provided a preliminary assessment to be used to assess the feasibility of the project in regards to biodiversity values and potential biodiversity offsetting costs. Specially, this assessment has detailed the potential impacts associated with one 'sediment removal option' and three flood mitigation options for the project.

Based on the field survey and results of the previously GHD (2018) assessment, the Bends Culvert 'sediment removal option' has the greatest impact to biodiversity. Approximately 2.3 ha of native vegetation and associated fauna habitat would be impacted by this option.

Both the Bends Culverts and Spots Complex options would impact upon TECs, Red-crowned Toadlet habitat, Powerful Owl habitat and Black Bittern habitat. Further survey would be required once indirect impacts are known to assess impact to threatened microbats.

The Oxford option on the other hand, would involve approximately 0.07 ha of non-TEC vegetation, and some impacts to fauna habitat.

It is unclear if biodiversity offsetting would be required for the options. In order to inform a biodiversity impact assessment for the preferred option, indirect impacts and the full extent of the works would need to be incorporated into one impact assessment, and Assessments of Significance completed for all impacted threatened entities.

In order to inform potential offsetting costs, an offsetting scenario was completed for each option using credit estimates and current credit pricing. It was concluded that the Bends Culvert 'sediment removal option' would be the most expensive option (estimated at $672K) The Sports Complex is likely to be the next expensive option (approximately $126K). The Bends Culverts option is estimated to be approximately $67K, whilst the Oxford option is estimated to be the cheapest at approximately $12K.

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Royal Haskoning DHV (2019) Wakehurst Parkway Flood Mitigation Feasibility Study

Annex 1. Likelihood of Occurrence Table of threatened Biodiversity in the study Area

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
Plants					
Acacia bynoeana	Bynoe's Wattle	E	V	Grows mainly in heath and dry sclerophyll forest in sandy soils. Mainly south of Dora Creek-Morisset area to Berrima and the Illawarra region, west to the Blue Mountains, also recorded from near Kurri Kurri in the Hunter Valley and from Morton National Park.	Low
Acacia pubescens	Downy Wattle	V	V	Concentrated around the Bankstown-Fairfield-Rookwood area and the Pitt Town area, with outliers occurring at Barden Ridge, Oakdale and Mountain Lagoon. Occurs on alluviums, shales and at the intergrade between shales and sandstones. The soils are characteristically gravely soils, often with ironstone. Grows in open woodland and forest, in a variety of plant communities, including Cooks River-Castlereagh Ironbark forest, Shale-Gravel Transition forest and Cumberland Plain woodland.	Low
Acacia terminalis subsp. terminalis	Sunshine Wattle	E	E	Very limited distribution, mainly in near-coastal areas from the northern shores of Sydney Harbour S to Botany Bay, with most records from the Port Jackson area and the eastern suburbs of Sydney. Coastal scrub and dry sclerophyll woodland on sandy soils. Habitat is generally sparse and scattered.	Low
Allocasuarina glareicola	-	E	E	Primarily restricted to the Richmond (NW Cumberland Plain) district, but with an outlier population found at Voyager Point, Liverpool. Grows in Castlereagh woodland on lateritic soil. Found in open woodland with Eucalyptus parramattensis, Eucalyptus fibrosa, Angophora bakeri, Eucalyptus sclerophylla and Melaleuca decora. Common associated understorey species include Melaleuca nodosa, Hakea dactyloides, Hakea sericea, Dillwynia tenuifolia, Micromyrtus minutiflora, Acacia elongata, Acacia brownei, Themeda australis and Xanthorrhoea minor.	Low
Asterolasia elegans	-	E	E	Occurs north of Sydney, in the Baulkham Hills, Hawkesbury and Hornsby local government areas. Also likely to occur in the western part of Gosford local government area. Known from only seven populations, only one of which is wholly within a conservation reserve. Occurs on	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				Hawkesbury sandstone in sheltered forests on mid- to lower slopes and valleys, e.g. in or adjacent to gullies which support sheltered forest.	
Caladenia tessellata	Thick-lip Spider Orchid	E	V	The Tessellated Spider Orchid is found in grassy sclerophyll woodland on clay loam or sandy soils, though the population near Braidwood is in low woodland with stony soil. Known from the Sydney area (old records), Wyong, Ulladulla and Braidwood in NSW. Populations in Kiama and Queanbeyan are presumed extinct.	Low
Callistemon linearifolius	Nettled Bottlebrush	V	-	Recorded from the Georges River to Hawkesbury River in the Sydney area, and north to the Nelson Bay area of NSW. Recorded in 2000 at Coalcliff in the northern Illawarra. For the Sydney area, recent records are limited to the Hornsby Plateau area near the Hawkesbury River. Grows in dry sclerophyll forest on the coast and adjacent ranges.	Low
Cryptostylis hunteriana	Leafless Tongue-orchid	V	V	Does not appear to have well defined habitat preferences and is known from a range of communities, including swamp-heath and woodland. The larger populations typically occur in woodland dominated by Scribbly Gum (Eucalyptus sclerophylla), Silvertop Ash (E. sieberi), Red Bloodwood (Corymbia gummifera) and Black Sheoak (Allocasuarina littoralis); appears to prefer open areas in the understorey of this community and is often found in association with the Large Tongue Orchid (C. subulata) and the Tartan Tongue Orchid (C. erecta).	Low
Cynanchum elegans	White-flowered Wax Plant	E	E	Recorded from rainforest gullies scrub and scree slopes from the Gloucester district to the Wollongong area and inland to Mt Dangar.	Low
Darwinia biflora	-	V	V	Recorded in Ku-ring-gai, Hornsby, Baulkham Hills and Ryde local government areas. The northern, southern, eastern and western limits of the range are at Maroota, North Ryde, Cowan and Kellyville, respectively. Occurs on the edges of weathered shale-capped ridges, where these intergrade with Hawkesbury Sandstone. The vegetation structure is usually woodland, open forest or scrub-heath.	Low
Deyeuxia appressa	-	E	E	A highly restricted NSW endemic known only from two pre-1942 records in the Sydney area (Herne Bay, Saltpan Creek, off the Georges River, south of Bankstown and Killara, near Hornsby). Almost nothing is known about the species' habitat and ecology. Flowers spring to summer and is mesophytic (grows in moist conditions).	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
Epacris purpurascens var. purpurascens	Port Jackson Heath	V	-	Recorded from Gosford in the north, to Narrabeen in the east, Silverdale in the west and Avon Dam vicinity in the South. Found in a range of habitat types, most of which have a strong shale soil influence.	Low
Eucalyptus camfieldii	Heart-leaved Stringybark	V	V	Restricted distribution in a narrow band with the most northerly records in the Raymond Terrace Area south to Waterfall. Localised and scattered distribution includes sites at Norah Head (Tuggerah Lakes), Peats Ridge, Mt Colah, Elvina Bay Trail (West Head), Terrey Hills, Killara, North Head, Menai, Wattamolla and a few other sites in Royal National Park. Poor coastal country in shallow sandy soils overlying Hawkesbury sandstone. Coastal heath mostly on exposed sandy ridges. Occurs mostly in small scattered stands near the boundary of tall coastal heaths and low open woodland of the slightly more fertile inland areas.	Low
Eucalyptus nicholii	Narrow-leaved Black Peppermint	V	V	Typically grows in dry grassy woodland, on shallow soils of slopes and ridges. Found primarily on infertile soils derived from granite or metasedimentary rock. Seedling recruitment is common, even in disturbed soils, if protected from grazing and fire.	Low
Eucalyptus scoparia	Wallangarra White Gum	E	V	In NSW it is known from only three locations near Tenterfield. Found in open eucalypt forest and woodland on well-drained granite hilltops, slopes and rocky outcrops, typically at high altitudes. At lower elevations can occur in less rocky soils in damp situations.	Low
Genoplesium baueri	Bauer's Midge Orchid	E	E	Grows in dry sclerophyll forest and moss gardens over sandstone. Flowers February to March. Has been recorded between Ulladulla and Port Stephens. Currently the species is known from just over 200 plants across 13 sites. The species has been recorded in Berowra Valley Regional Park, Royal National Park and Lane Cove National Park and may also occur in the Woronora, Oâ€™Hares, Metropolitan and Warragamba Catchments.	Low
Grevillea caleyi	Caley's Gravillea	E	E	Restricted to an 8 km square area around Terrey Hills, approximately 20 km north of Sydney. Occurs in three major areas of suitable habitat, namely Belrose, Ingleside and Terrey Hills-Duffys forest within the Ku-ring-gai, Pittwater and Warringah Local Government Areas. All sites occur on the ridgetop between elevations of 170 to 240m asl, in association with laterite soils and a vegetation community of open	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				forest, generally dominated by Eucalyptus sieberi and Corymbia gummifera. Commonly found in the endangered Duffys forest ecological community.	
Grevillea shiressii	Grevillea shiressii	V	V	Grows along creek banks in wet sclerophyll forest with a moist understorey in alluvial sandy or loamy soils.	Low
Haloragodendron lucasii	-	E	E	Occurs on Hawkesbury Sandstone in moist sandy loam soil. The species prefers sheltered aspects and inhabits gentle slopes below cliff lines near creeks in low open woodland or open forest. Its distribution is correlated with high soil moisture and phosphorus levels.	Low
Hibbertia superans	Hibbertia superans	E	-	Flowering time is July to December. The species occurs on sandstone ridgetops often near the shale-sandstone boundary. Occurs in both open woodland and heathland, and appears to prefer open disturbed areas, such as tracksides.	Low
Isotoma fluviatilis subsp. fluviatilis	-	Extinct	-	Known to grow in damp places, on the Cumberland Plain, including freshwater wetland, grassland/alluvial woodland and an alluvial woodland/shale plains woodland (Cumberland Plain Woodland) ecotone.	None
Kunzea rupestris	Kunzea rupestris	V	V	Grows in shallow depressions on large flat sandstone rock outcrops. Characteristically found in short to tall shrubland or heathland.	None
Lasiopetalum joyceae	Lasiopetalum joyceae	V	V	Grows in heath on sandstone.	None
Leptospermum deanei	Leptospermum deanei	V	V	woodland on lower hill slopes or near creeks. Sandy alluvial soil or sand over sandstone. Occurs in riparian scrub, woodland and open forest.	None
Melaleuca biconvexa	Biconvex Paperbark	V	V	Grows in damp places, often near streams or low-lying areas on alluvial soils of low slopes or sheltered aspects. Scattered and dispersed populations found in the Jervis Bay area in the south and the Gosford-Wyong area in the north.	Low
Melaleuca deanei	Deane\'s Paperbark	V	V	Grows in wet heath on sandstone in coastal districts from Berowra to Nowra.	None
Microtis angusii	Angus's Onion Orchid	E	E	It is not easy to define the preferred natural habitat of this orchid as the Ingleside location is highly disturbed. The dominant species occurring on the site are introduced weeds Coolatai grass and Acacia saligna. The Ingleside population occurs on soils that have been modified but were	None

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				originally those of the restricted ridgetop lateritic soils in the Duffys forest - Terrey Hills - Ingleside and Belrose areas. These soils support a specific and distinct vegetation type, the Duffys forest Vegetation Community which is listed as an EEC under the TSC Act and ranges from open forest to low open forest and rarely woodland.	
Pelargonium sp. Striatellum (G.W.Carr 10345)	-	E	E	It has a narrow habitat that is usually just above the high-water level of irregularly inundated or ephemeral lakes, in the transition zone between surrounding grasslands or pasture and the wetland or aquatic communities.	Low
Persoonia hirsuta	Hairy Geebung	E	E	Distributed from Singleton in the north, along the east coast to Bargo in the south and the Blue Mountains to the west. A large area of occurrence, but occurs in small populations, increasing the species's fragmentation in the landscape. Found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone. Usually present as isolated individuals or very small populations. Probably killed by fire (as other Persoonia spp. are) but will regenerate from seed.	None
Persoonia mollis subsp. maxima	Persoonia mollis subsp. maxima	E	E	Occurs in sheltered aspects of deep gullies or on the steep upper hillsides of narrow gullies on Hawkesbury Sandstone. These habitats support relatively moist, tall forest vegetation communities, often with warm temperate rainforest influences. Flowers are likely to be pollinated predominantly by native bees. Self-pollination is usually unsuccessful.	None
Pimelea curviflora var. curviflora	-	V	V	Confined to the coastal area of Sydney between northern Sydney in the south and Maroota in the north-west. Former range extended south to the Parramatta River and Port Jackson region including Five Dock, Bellevue Hill and Manly. Occurs on shaley-lateritic soils over sandstone and shale-sandstone transition soils on ridgetops and upper slopes amongst woodlands.	None
Pimelea spicata	Spiked Rice-flower	E	E	Once widespread on the Cumberland Plain, the Spiked Rice-flower occurs in two disjunct areas; the Cumberland Plain (Narellan, Marayong, Prospect Reservoir areas) and the Illawarra (Landsdowne to Shellharbour to northern Kiama). In both the Cumberland Plain and Illawarra environments this species is found on well-structured clay	None

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				soils. On the inland Cumberland Plain sites it is associated with grey box and Ironbark. In the coastal Illawarra it occurs commonly in Coast Banksia open woodland with a better developed shrub and grass understorey.	
Prostanthera densa	Villous Mintbush	V	V	Villous Mintbush is generally grows in sclerophyll forest and shrubland on coastal headlands and near coastal ranges, chiefly on sandstone, and rocky slopes near the sea.	None
Prostanthera marifolia	Seaforth Mintbush	CE	CE	Occurs in localised patches in or in close proximity to the endangered Duffys forest ecological community. Located on deeply weathered clay-loam soils associated with ironstone and scattered shale lenses, a soil type which only occurs on ridge tops and has been extensively urbanised.	None
Syzygium paniculatum	Magenta Lilly Pilly	E	V	Found only in NSW, in a narrow, linear coastal strip from Bulahdelah to Conjola State forest. On the south coast the species occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral rainforest. On the central coast it occurs on gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities	Low
Tetratheca glandulosa	Tetratheca glandulosa	V	V	Associated with shale-sandstone transition habitat where shale-cappings occur over sandstone, with associated soil landscapes such as Lucas Heights, Gymea, Lambert and Faulconbridge. Topographically, the plant occupies ridgetops, upper-slopes and to a lesser extent mid-slope sandstone benches. Soils are generally shallow, consisting of a yellow, clayey-sandy loam. Stony lateritic fragments are also common in the soil profile on many of these ridgetops. Vegetation structure varies from heaths and scrub to woodlands-open woodlands, and open forest.	None
Thesium australe	Austral Toadflax	V	V	Grows in very small populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. It is also found in Tasmania and Queensland and in eastern Asia. Occurs in grassland or grassy woodland. Grows on kangaroo grass tussocks but has also been recorded within the exotic coolatai grass.	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
Triplarina imbricata	Creek Triplarina	E	E	Found only in a few locations in the ranges south-west of Glenreagh and near Tabulam in north-east NSW. Along watercourses in low open forest with water gum.	Low
Threatened Fauna					
Heleioporus australiacus	Giant Burrowing Frog	V	V	The Giant Burrowing Frog has been recorded breeding in a range of water bodies associated with more sandy environments of the coast and adjacent ranges from the Sydney Basin south the eastern Victoria. It breeds in hanging swamps, perennial non-flooding creeks and occasionally permanent pools, but permanent water must be present to allow its large tadpoles time to reach metamorphosis.	Moderate
Litoria aurea	Green and Golden Bell Frog	E	V	Inhabits a very wide range of water bodies including marshes, dams and streams, particularly those containing emergent vegetation such as bullrushes or spikerushes. It also inhabits numerous types of man-made water bodies including quarries and sand extraction sites. Optimum habitat includes water-bodies that are un-shaded, free of predatory fish such as Plague Minnow, have a grassy area nearby and diurnal sheltering sites available.	None
Litoria littlejohni	Littlejohn's Tree Frog	V	V	Occurs in wet and dry sclerophyll forests and heathland associated with sandstone outcrops between 280 and 1000 m on the eastern slopes of the Great Dividing Range from the Central Coast down into Victoria. Individuals have been collected from a wide range of water bodies that includes semi-permanent dams, permanent ponds, temporary pools and permanent streams, with calling occurring from fringing vegeation or on the banks. Individuals have been observed sheltering under rocks on high exposed ridges during summer and within deep leaf litter adjacent to the breeding site. Calling occurs in all months of the year, often in association with heavy rains. The tadpoles are distinctive, being large and very dark in colouration.	None
Mixophyes balbus	Stuttering Frog	E	V	Associated with streams in dry sclerophyll and wet sclerophyll forests and rainforests of more upland areas of the Great Dividing Range of NSW and down into Victoria. Breeding occurs along forest streams with permanent water where eggs are deposited within nests excavated in riffle zones by the females and the tadpoles swim free into the stream	None

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				when large enough to do so. Outside of breeding, individuals range widely across the forest floor and can be found hundres of metres from water	
Pseudopryne	Red-crowned Toadlet	V	-	Red-crowned Toadlets are quite a localised species that appear to be largely restricted to the immediate vicinity of suitable breeding habitat. Red-crowned Toadlets are usually found as small colonies scattered along ridges coinciding with the positions of suitable refuges near breeding sites. Due to this tendency for discrete populations to concentrate at particular sites, a relatively small localised disturbance may have a significant impact on a local population if it occurs on a favoured breeding or refuge site.	Moderate
Actitis hypoleucos	Common Sandpiper	-	M, MA, C, J, K	Utilises a wide range of coastal wetlands and some inland wetlands, mostly found around muddy margins or rocky shores. Forages in shallow water and on soft mud, roosts on rocks or vegetation such as mangroves. Northern hemisphere breeding.	Low
Cuculus optatus	Oriental Cuckoo	-	MA	Mainly inhabits coniferous, deciduous and mixed forests. Breeds in northern hemisphere. Brood parasite, laying eggs in nests of other birds.	Low
Pandion cristatus	Eastern Osprey	V	M, MA	Found right around the Australian coast line, except for Victoria and Tasmania. They are common around the northern coast, especially on rocky shorelines, islands and reefs. The species is uncommon to rare or absent from closely settled parts of south-eastern Australia. Favour coastal areas, especially the mouths of large rivers, lagoons and lakes. Feed on fish over clear, open water.	Moderate
Rostratula australis	Painted Snipe	E	E, MA	In NSW, this species has been recorded at the Paroo wetlands, Lake Cowell, Macquarie Marshes and Hexham Swamp. Most common in the Murray-Darling Basin. Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds.	Low
Anthochaera phrygia	Regent Honeyeater	CE	E,M	The Regent Honeyeater mainly inhabits temperate woodlands and open forests of the inland slopes of south-east Australia. Birds are also found in drier coastal woodlands and forests in some years. The distribution of	None

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				the species has contracted dramatically in the last 30 years to between north-eastern Victoria and south-eastern Queensland. There are only three known key breeding regions remaining: north-east Victoria (Chiltern-Albury), and in NSW at Capertee Valley and the Bundarra-Barraba region. In NSW the distribution is very patchy and mainly confined to the two main breeding areas and surrounding fragmented woodlands. In some years flocks converge on flowering coastal woodlands and forests.	
Artamus cyanopterus cyanopterus	Dusky Wood Swallow	V		dry, open eucalypt forests and woodlands, including mallee associations, with an open or sparse understorey of eucalypt saplings, acacias and other shrubs, and ground-cover of grasses or sedges and fallen woody debris. It has also been recorded in shrublands, heathlands and very occasionally in moist forest or rainforest. Also found in farmland, usually at the edges of forest or woodland.	Low
Botaurus poiciloptilus	Australasian Bittern	E	E	The Australasian Bitterns is widespread but uncommon over south-eastern Australia. In NSW they may be found over most of the state except for the far north-west. Favours permanent freshwater wetlands with tall, dense vegetation, particularly bullrushes and spikerushes.	Low
Burhinus grallarius	Bush Stone-curlew	E	-	The Bush Stone-curlew is found throughout Australia except for the central southern coast and inland, the far south-east corner, and Tasmania. Only in northern Australia is it still common however and in the south-east it is either rare or extinct throughout its former range. Inhabits open forests and woodlands with a sparse grassy groundlayer and fallen timber. Largely nocturnal, being especially active on moonlit nights.	None
Calidris acuminata	Sharp-tailed Sandpiper	-	M	the Sharp-tailed Sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. This includes lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and hypersaline saltlakes inland. They also occur in saltworks and sewage farms. They use flooded paddocks, sedgelands and other ephemeral wetlands, but leave when they dry. They use intertidal mudflats in sheltered bays, inlets, estuaries or seashores, and	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				also swamps and creeks lined with mangroves. They tend to occupy coastal mudflats mainly after ephemeral terrestrial wetlands have dried out, moving back during the wet season. They may be attracted to mats of algae and water weed either floating or washed up around terrestrial wetlands, and coastal areas with much beachcast seaweed. Sometimes they occur on rocky shores and rarely on exposed reefs	
Calidris ferruginea	Curlew Sandpiper	E	-	The Curlew Sandpiper is distributed around most of the coastline of Australia. It occurs along the entire coast of NSW, particularly in the Hunter Estuary, and sometimes in freshwater wetlands in the Murray-Darling Basin. It generally occupies littoral and estuarine habitats, and in New South Wales is mainly found in intertidal mudflats of sheltered coasts. It also occurs in non-tidal swamps, lakes and lagoons on the coast and sometimes the inland	Low
Calidris melanotos	Pectoral Sandpiper	-	M	the Pectoral Sandpiper prefers shallow fresh to saline wetlands. The species is found at coastal lagoons, estuaries, bays, swamps, lakes, inundated grasslands, saltmarshes, river pools, creeks, floodplains and artificial wetlands.	Low
Callocephalon fimbriatum	Gang-gang Cockatoo	V	-	In summer, occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests. Also occur in subalpine snow gum woodland and occasionally in temperate or regenerating forest. In winter, occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas. It requires tree hollows in which to breed.	Low
Callocephalon fimbriatum	Gang-gang Cockatoo population in the Hornsby and Ku-ring-gai local government areas	EP	-	In summer, occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests. Also occur in subalpine snow gum woodland and occasionally in temperate or regenerating forest. In winter, occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas. It requires tree hollows in which to breed.	Low
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	-	Inhabits forest with low nutrients, characteristically with key Allocasuarina spp. Tends to prefer drier forest types with a middle	Moderate

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				stratum of Allocasuarina below Eucalyptus or Angophora. Often confined to remnant patches in hills and gullies. Breed in hollows stumps or limbs, either living or dead. Endangered population in the Riverina.	
Daphoenositta chrysoptera	Varied Sittella	V	-	Inhabits wide variety of dry eucalypt forests and woodlands, usually with either shrubby under storey or grassy ground cover or both, in all climatic zones of Australia. Usually in areas with rough-barked trees, such as stringybarks or ironbarks, but also in paperbarks or mature Eucalypts with hollows.	Moderate
Dasyornis brachypterus	Eastern Bristlebird	E	E	Found in coastal woodlands, dense scrub and heathlands, particularly where it borders taller woodlands.	Low
Glossopsitta pusilla	Little Lorikeet	V	-	Distributed in forests and woodlands from the coast to the western slopes of the Great Dividing Range in NSW, extending westwards to the vicinity of Albury, Parkes, Dubbo and Narrabri. Mostly occur in dry, open eucalypt forests and woodlands. They feed primarily on nectar and pollen in the tree canopy. Nest hollows are located at heights of between 2 m and 15 m, mostly in living, smooth-barked eucalypts. Most breeding records come from the western slopes.	Low
Grantiella picta	Painted Honeyeater	V	-	The Painted Honeyeater is nomadic and occurs at low densities throughout its range. The greatest concentrations of the bird and almost all breeding occurs on the inland slopes of the Great Dividing Range in NSW, Victoria and southern Queensland. During the winter it is more likely to be found in the north of its distribution. Inhabits boree, brigalow and box-gum woodlands and box-ironbark forests.	Low
Haliaeetus leucogaster	White-bellied Sea-Eagle	-	M	Inhabits coastal and near coastal areas, building large stick nests, and feeding mostly on marine and estuarine fish and aquatic fauna.	Low
Hieraaetus morphnoides	Little Eagle	V	-	Most abundant in lightly timbered areas with open areas nearby. Often recorded foraging in grasslands, crops, treeless dune fields, and recently logged areas. May nest in farmland, woodland and forest in tall trees.	Low
Hirundapus caudacutus	White-throated Needletail	-	M	An aerial species found in feeding concentrations over cities, hilltops and timbered ranges.	Low
Ixobrychus flavicollis	Black Bittern	V	-	Usually found on coastal plains below 200 m. Often found along timbered watercourses, in wetlands with fringing trees and shrub	Moderate

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				vegetation. The sites where they occur are characterized by dense waterside vegetation.	
Lathamus discolor	Swift Parrot	E	E	The Swift Parrot occurs in woodlands and forests of NSW from May to August, where it feeds on eucalypt nectar, pollen and associated insects. The Swift Parrot is dependent on flowering resources across a wide range of habitats in its wintering grounds in NSW. This species is migratory, breeding in Tasmania and also nomadic, moving about in response to changing food availability.	Low
Lophoictinia isura	Square-tailed Kite	V	-	Typically inhabits coastal forested and wooded lands of tropical and temperate Australia. In NSW it is often associated with ridge and gully forests dominated by Eucalyptus longifolia, Corymbia maculata, E. elata or E. smithii. Individuals appear to occupy large hunting ranges of more than 100km2. They require large living trees for breeding, particularly near water with surrounding woodland -forest close by for foraging habitat. Nest sites are generally located along or near watercourses, in a tree fork or on large horizontal limbs.	Low
Monarcha melanopsis	Black-faced Monarch	-	M	Found along the coast of eastern Australia, becoming less common further south. Inhabits rainforests, eucalypt woodlands, coastal scrub and damp gullies. It may be found in more open woodland when migrating.	Low
Monarcha trivirgatus	Spectacled Monarch	-	M	Coastal north-eastern and eastern Australia, including coastal islands, from Cape York, Queensland to Port Stephens, New South Wales. Prefers thick understorey in rainforests, wet gullies and waterside vegetation, as well as mangroves.	Low
Motacilla flava	Western Yellow Wagtail	-	M	This species occupies a range of damp or wet habitats with low vegetation, from damp meadows, marshes, waterside pastures, sewage farms and bogs to damp steppe and grassy tundra. In the north of its range it is also found in large forest clearings.	Low
Myiagra cyanoleuca	Satin Flycatcher	-	M	The Satin Flycatcher is found along the east coast of Australia from far northern Queensland to Tasmania, including south-eastern South Australia. Found in tall forests, preferring wetter habitats such as heavily forested gullies, but not rainforests.	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
Ninox connivens	Barking Owl	V	-	Generally found in open forests, woodlands, swamp woodlands and dense scrub. Can also be found in the foothills and timber along watercourses in otherwise open country.	Low
Ninox strenua	Powerful Owl	V	-	Occupies wet and dry eucalypt forests and rainforests. Can occupy both un-logged and lightly logged forests as well as undisturbed forests where it usually roosts on the limbs of dense trees in gully areas. It is most commonly recorded within red turpentine in tall open forests and black she-oak within open forests. Large mature trees with hollows at least 0.5 m deep are required for nesting. Tree hollows are particularly important for the Powerful Owl because a large proportion of the diet is made up of hollow-dependent arboreal marsupials. Nest trees for this species are usually emergent with a diameter at breast height of at least 100 cm.	Moderate
Numenius madagascariensis	Far Eastern Curlew	CE	M, MA	Generally forages on intertidal mudflats, along the muddy banks of estuaries and in coastal lagoons, either in open unvegetated areas or among mangroves. They sometimes forage on sandy beaches or among rocks	Low
Petroica boodang	Scarlet Robin	V	-	The Scarlet Robin is found from SE Queensland to SE South Australia and also in Tasmania and SW Western Australia. In NSW, it occurs from the coast to the inland slopes. The Scarlet Robin lives in dry eucalypt forests and woodlands. The understorey is usually open and grassy with few scattered shrubs.	Low
Ptilinopus superbus	Superb Fruit-dove	V	-	The Superb Fruit-dove occurs principally from north-eastern in Queensland to north-eastern NSW. It is much less common further south, where it is largely confined to pockets of suitable habitat as far south as Moruya. There are records of vagrants as far south as eastern Victoria and Tasmania. Inhabits rainforest and similar closed forests where it forages high in the canopy, eating the fruits of many tree species such as figs and palms. It may also forage in eucalypt or acacia woodland where there are fruit-bearing trees.	Low
Rhipidura rufifrons	Rufous Fantail	-	M	Found along the east coast of Australia from far northern Queensland to Tasmania, including south-eastern South Australia. Inhabits tall	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				forests, preferring wetter habitats such as heavily forested gullies, but not rainforests.	
Rostratula australis	Australian Painted Snipe	E	E, M	In NSW, this species has been recorded at the Paroo wetlands, Lake Cowell, Macquarie Marshes and Hexham Swamp. Most common in the Murray-Darling Basin. Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds.	Low
Tyto novaehollandiae	Masked Owl	V	-	Inhabits a diverse range of wooded habitat that provide tall or dense mature trees with hollows suitable for nesting and roosting. Mostly recorded in open forest and woodlands adjacent to cleared lands. Nest in hollows, in trunks and in near vertical spouts or large trees, usually living but sometimes dead. Nest hollows are usually located within dense forests or woodlands. Masked owls prey upon hollow-dependent arboreal marsupials, but terrestrial mammals make up the largest proportion of the diet.	Low
Tyto tenebricosa	Sooty Owl	V	-	Often found in tall old-growth forests, including temperate and subtropical rainforests. In NSW mostly found on escarpments with a mean altitude less than 500 metres. Nests and roosts in hollows of tall emergent trees, mainly eucalypts often located in gullies. Nests have been located in trees 125 to 161 centimetres in diameter.	Moderate
Macquaria australasica	Macquarie Perch	E	E	Recent research indicates that there may be at least two distinct forms of Macquarie Perch, one from the western rivers (Murray-Darling Basin form) and one from the eastern rivers (the Shoalhaven and Hawkesbury-Nepean systems) (the coastal form). The species has also been stocked or translocated into a number of reservoirs including Talbingo, Cataract and Khancoban reservoirs and translocated into streams including the Mongarlowe River. Macquarie Perch are found in both river and lake habitats; especially the upper reaches of rivers and their tributaries	None
Prototroctes maraena	Australian Grayling	-	V	Historically, this species occurred in coastal streams from the Grose River Valley, southwards through NSW, Vic. and Tas. It also occasionally occurred high upstream in the Snowy R. A single juvenile specimen was	None

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				collected from Lake Macquarie in 1974. This species spends only part of its lifecycle in freshwater. The Tambo River population inhabits a clear, gravel-bottomed stream with alternating pools and riffles, and granite outcrops. It has also been associated with clear, gravel-bottomed habitats in the Mitchell & Wonnangatta Rivers but was present in a muddy-bottomed, heavily silted habitat in the Tarwin R.	
Pommerhelix duralensis	Dural Land Snail	E	E	The species has a strong affinity for communities in the interface region between shale-derived and sandstone-derived soils, with forested habitats that have good native cover and woody debris. It favours sheltering under rocks or inside curled-up bark.	None
Cercartetus nanus	Eastern Pygmy-possum	V	-	Inhabits rainforest through to sclerophyll forest and tree heath. Banksias and myrtaceous shrubs and trees are a favoured food source. Will often nest in tree hollows, but can also construct its own nest. Because of its small size it is able to utilise a range of hollow sizes including very small hollows. Individuals will use a number of different hollows and an individual has been recorded using up to 9 nest sites within a 0.5ha area over a 5 month period.	Low
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Located in a variety of drier habitats, including the dry sclerophyll forests and woodlands to the east and west of the Great Dividing Range. Can also be found on the edges of rainforests and in wet sclerophyll forests. This species roosts in caves and mines in groups of between 3 and 37 individuals.	Moderate
Dasyurus maculatus maculatus	Spotted-tailed Quoll	V	E	Spotted-tailed Quoll are found on the east coast of NSW, Tasmania, eastern Victoria and north-eastern Queensland. Only in Tasmania is it still considered common. Recorded across a range of habitat types, including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline.	Low
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	-	Inhabit sclerophyll forests, preferring wet habitats where trees are more than 20 m high. Two observations have been made of roosts in stem holes of living eucalypts. There is debate about whether or not this species moves to lower altitudes during winter, or whether they remain sedentary but enter torpor. This species also appears to be	Moderate

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				highly mobile and records showing movements of up to 12 km between roosting and foraging sites.	
Isoodon obesulus obesulus	Southern Brown Bandicoot (eastern)	E	-	Prefers sandy soils with scrubby vegetation and-or areas with low ground cover that are burn from time to time. A mosaic of post fire vegetation is important for this species.	Low
Miniopterus australis	Little Bentwing-bat	V	-	Coastal north-eastern NSW and eastern Queensland. Little Bent-wing Bat is an insectivorous bat that roost in caves, in old mines, in tunnels, under bridges, or in similar structures. They breed in large aggregations in a small number of known caves and may travel 100s km from feeding home ranges to breeding sites. Little Bent-wing Bat has a preference for moist eucalypt forest, rainforest or dense coastal banksia scrub where it forages below the canopy for insects.	Moderate
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V	-	Eastern Bent-wing Bats occur along the east and north-west coasts of Australia. Caves are the primary roosting habitat, but also use derelict mines, storm-water tunnels, buildings and other man-made structures. Form discrete populations centred on a maternity cave that is used annually in spring and summer for the birth and rearing of young.	Moderate
Mormopterus norfolkensis	Eastern Freetail-bat	V	-	Most records are from dry eucalypt forests and woodlands to the east of the Great Dividing Range. Appears to roost in trees, but little is known of this species' habits.	Moderate
Myotis macropus	Southern Myotis	V	-	The Large-footed Myotis is found in the coastal band from the north-west of Australia, across the top-end and south to western Victoria. Generally roost in groups of 10 - 15 close to water in caves, mine shafts, hollow-bearing trees, and storm water channels, buildings, under bridges and in dense foliage.	Moderate
Petauroides volans	Greater Glider population in the Eurobodalla local government area	V	-	The Greater Glider is an arboreal marsupial, largely restricted to eucalypt forests and woodlands. It is primarily folivorous, with a diet mostly comprising eucalypt leaves, and occasionally	Low
Petaurus norfolcensis	Squirrel Glider	V	-	Generally occurs in dry sclerophyll forests and woodlands but is absent from dense coastal ranges in the southern part of its range. Requires abundant hollow bearing trees and a mix of eucalypts, banksias and acacias. There is only limited information available on den tree use by	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
				Squirrel gliders, but it has been observed using both living and dead trees as well as hollow stumps. Within a suitable vegetation community at least one species should flower heavily in winter and one species of eucalypt should be smooth barked. Endangered population in the Wagga Wagga LGA.	
Petaurus norfolcensis	Squirrel Glider on Barrenjoey Peninsula, north of Bushrangers Hill	EP	-	Generally occurs in dry sclerophyll forests and woodlands but is absent from dense coastal ranges in the southern part of its range. Requires abundant hollow bearing trees and a mix of eucalypts, banksias and acacias. There is only limited information available on den tree use by Squirrel gliders, but it has been observed using both living and dead trees as well as hollow stumps. Within a suitable vegetation community at least one species should flower heavily in winter and one species of eucalypt should be smooth barked. Endangered population in the Wagga Wagga LGA.	None
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	Found in rocky areas in a wide variety of habitats including rainforest gullies, wet and dry sclerophyll forest, and open woodland and rocky outcrops in semi-arid country. Commonly sites have a northerly aspect with numerous ledges, caves and crevices.	None
Phascolarctos cinereus	Koala	V	V	Inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall.	Low
Phascolarctos cinereus	Koala in the Pittwater Local Government Area	EP	-	Inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall.	None
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	V	Inhabits coastal heath and wet and dry sclerophyll forests. Generally found in areas with rainfall greater than 760 mm. Requires relatively thick ground cover where the soil is light and sandy.	Low
Pseudomys novaehollandiae	New Holland Mouse	-	V	The New Holland Mouse currently has a disjunct, fragmented distribution across Tasmania, Victoria, New South Wales and Queensland. Across the species' range the New Holland Mouse is known to inhabit open heathlands, open woodlands with a heathland understorey, and vegetated sand dunes.	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence within area of direct disturbance
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	This species is a canopy-feeding frugivore and nectarivore of rainforests, open forests, woodlands, melaleuca swamps and banksia woodlands. Bats commute daily to foraging areas, usually within 15 km of the day roost although some individuals may travel up to 70 km.	Moderate
Scoteanax rueppellii	Greater Broad-nosed Bat	V	-	Prefer moist gullies in mature coastal forests and rainforests, between the Great Dividing Range and the coast. They are only found at low altitudes below 500 m. In dense environments they utilise natural and human-made opening in the forest for flight paths. Creeks and small rivers are favoured foraging habitat. This species roosts in hollow tree trunks and branches.	Moderate
Hoplocephalus bungaroides	Broad-headed Snake	E	V	Occurs almost exclusively in association with communities occurring on Triassic sandstone within the Sydney Basin. Typically found among exposed sandstone outcrops with vegetation types ranging from woodland to heath. Within these habitats they spend most of the year sheltering in and under rock crevices and exfoliating rock. However, some individuals will migrate to tree hollows to find shelter during hotter parts of summer.	None
Varanus rosenbergi	Rosenberg's Goanna	V	-	This species is a Hawkesbury-Narrabeen sandstone outcrop specialist. Occurs in coastal heaths, humid woodlands and both wet and dry sclerophyll forests.	Low

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Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)

APPENDIX F - Sand Sheet Investigation Report

northern beaches council

Hand Auger Sample Plan 1

OXFORD FALLS, NSW

DRAFT

Legend

— Study Reach

— Watercourse (LPI)

Hand Auger Site

● Sand Lense or Flood Couplet

● No Clean Sand Deposit (Silts & Clays)

● Clean Sand Deposit Recorded

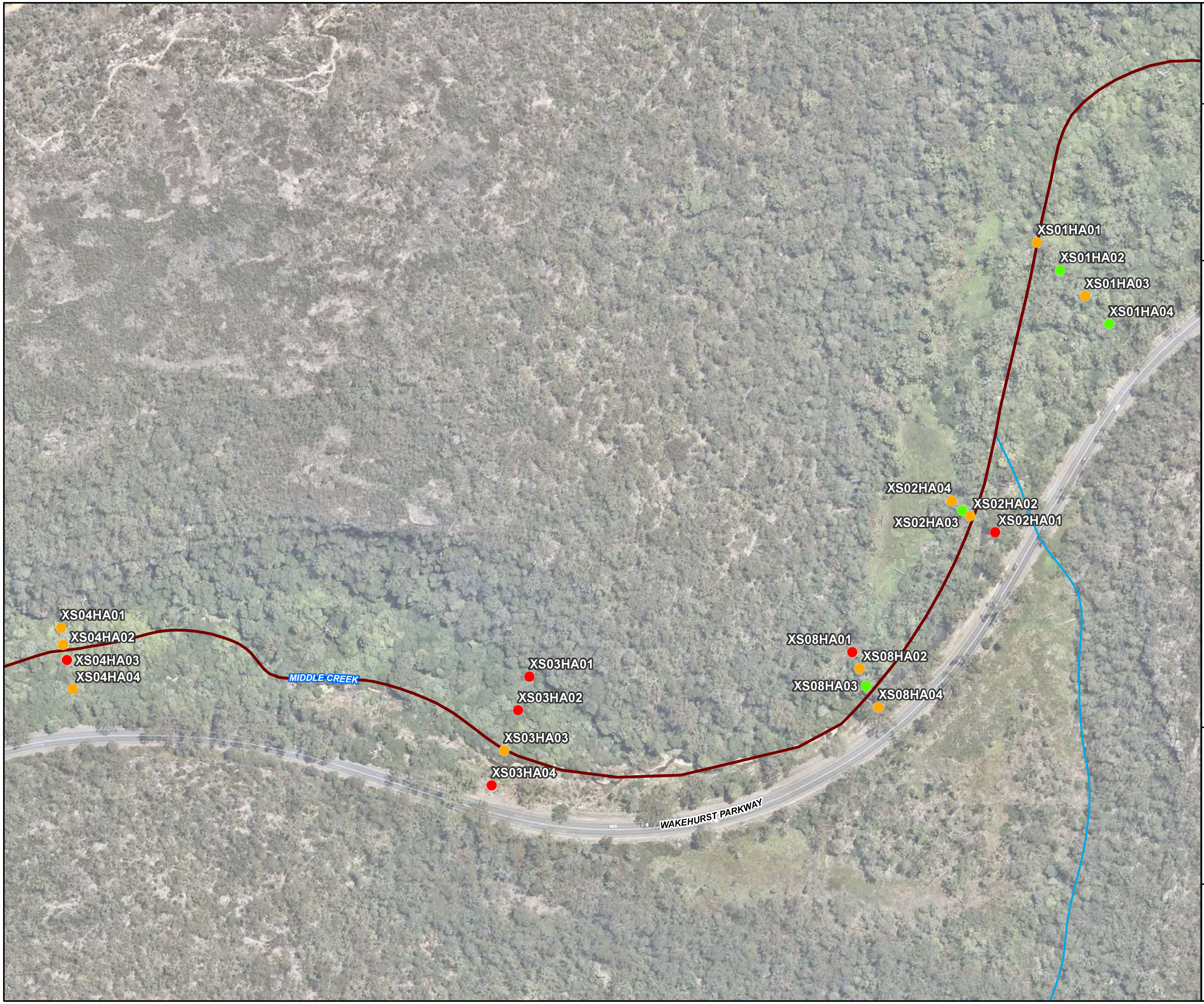
NSW GOVERNMENT | Soil Conservation Service

1:1,500 Scale at A3

0 20 40 60 80 m

N

Map Produced by SCS Hornsby
Date: 2018-12-17
Coordinate System: GDA 1994 MGA Zone 56
Map: SCS3036-1-GS-002-HandAugerPlan 1.mxd 01
Aerial Imagery supplied by nearmap (January, 2018)



northern beaches council

Hand Auger Sample Plan 2

OXFORD FALLS, NSW

DRAFT

Legend

- Study Reach
- Watercourse (LPI)

Hand Auger Site

- 🟠 Sand Lense or Flood Couplet
- 🔴 No Clean Sand Deposit (Silts & Clays)
- 🟢 Clean Sand Deposit Recorded

NSW GOVERNMENT | Soil Conservation Service

1:2,000 Scale at A3

0 20 40 60 80 m

N

Map Produced by SCS Hornsby
Date: 2018-12-17
Coordinate System: GDA 1994 MGA Zone 56
Map: SCS3036-1-GS-003-HandAugerPlan 2.mxd 01
Aerial Imagery supplied by nearmap (January, 2018)

northern beaches council

Hand Auger Sample Plan

OXFORD FALLS, NSW

DRAFT

Legend

- Study Reach
- Watercourse (LPI)

Hand Auger Site

- 🟠 Sand Lense or Flood Couplet
- 🔴 No Clean Sand Deposit (Silts & Clays)
- 🟢 Clean Sand Deposit Recorded

NSW GOVERNMENT | Soil Conservation Service

1:3,500 Scale at A3

0 20 40 60 80 m

N

Map Produced by SCS Hornsby
Date: 2018-12-17
Coordinate System: GDA 1994 MGA Zone 56
Map: SCS3036-1-GS-004-HandAugerPlan.mxd 01
Aerial Imagery supplied by nearmap (January, 2018)

Soil Conservation Service

HAND AUGER LOG XS01-HA01

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

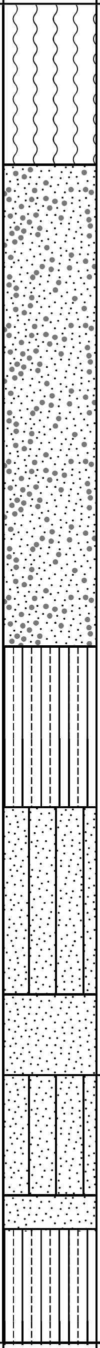
COORDINATES 338242.7, 6267949
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.67

COMMENTS

LOGGED BY RMH

Depth (m): 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2

Graphic Log



Moisture	Material Description
D	Sandy LOAM (Top Soil) Brown, moist, slight to just firm. Organics, roots.
	SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Fine grained.
	Sandy Clay LOAM Brown, moist, strong.
	Loamy SAND Grey, moist. Medium grained.
	SAND Yellow, moist, loose. Medium to coarse grained.
W	Loamy SAND Grey, wet.
	SAND Yellow, wet. Coarse grained.
	Sandy Clay LOAM Dark brown, wet, strong.
	Termination Depth at:2 m

R. L (m): 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2, 2.1, 2, 1.9, 1.8, 1.7, 1.6

Disclaimer This bore log is intended for environmental not geotechnical purposes.

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Soil Conservation Service

HAND AUGER LOG XS01-HA02

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

COORDINATES 338255.4, 6267934
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.20

COMMENTS

LOGGED BY RMH

Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
		D	LOAM (Top Soil) Brown, moist, spongy to firm. Organics, roots, charcoal fragments at 0.36	
0.1				3.1
0.2				3
0.3				2.9
			SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Fine grained.	
0.4				2.8
0.5				2.7
			Sandy Clay LOAM Brown, moist, strong.	
0.6				2.6
			SAND Yellow, moist, loose. Medium grained.	
0.7				2.5
0.8		W	SAND Grey, wet. Medium grained.	2.4
0.9				2.3
1				2.2
			SAND Light yellow, wet. Gravels at 1.4m.	
1.1				2.1
1.2				2
1.3				1.9
1.4				1.8
			Sandy LOAM Grey, wet. Medium grained.	
1.5				1.7
1.6			Loamy SAND Grey, wet. Medium grained.	1.6
1.7				1.5
1.8				1.4
1.9				1.3
2			Termination Depth at:2 m	1.2

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produced by ESlog.ESdat.net on 07 Jan 2019

Soil Conservation Service

HAND AUGER LOG XS01-HA03

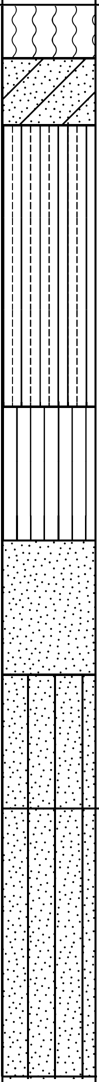
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

COORDINATES 338269.2, 6267920
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.24

COMMENTS

LOGGED BY RMH



Depth (m)	Moisture	Material Description	R. L (m)
	D	LOAM (Top Soil) Brown, moist, spongy to firm. Organics, roots.	3.2
0.1 0.2		Clayey SAND Brown with minor yellow clean sand lense, moist. Fine grained.	3.1
0.3 0.4 0.5		Silty LOAM Brown, moist, firm.	3 2.9 2.8 2.7
0.6 0.7		Sandy LOAM Brown, moist, slight to firm.	2.6 2.5
0.8 0.9		SAND Orange/Yellow, moist. Fine grained.	2.4 2.3
1 1.1		Loamy SAND Grey, moist. Fine grained	2.2 2.1
1.2 1.3 1.4 1.5	W	Loamy SAND Orange/Yellow, wet. Fine grained, colour change at 1.40 m to grey.	2 1.9 1.8 1.7
1.6 1.7 1.8 1.9		Borehole completed at 1.60 m (Water table reached therefore no sample could be obtained)	1.6 1.500 1.400 1.300
2		Termination Depth at:2 m	1.200

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Soil Conservation Service

HAND AUGER LOG XS01-HA04

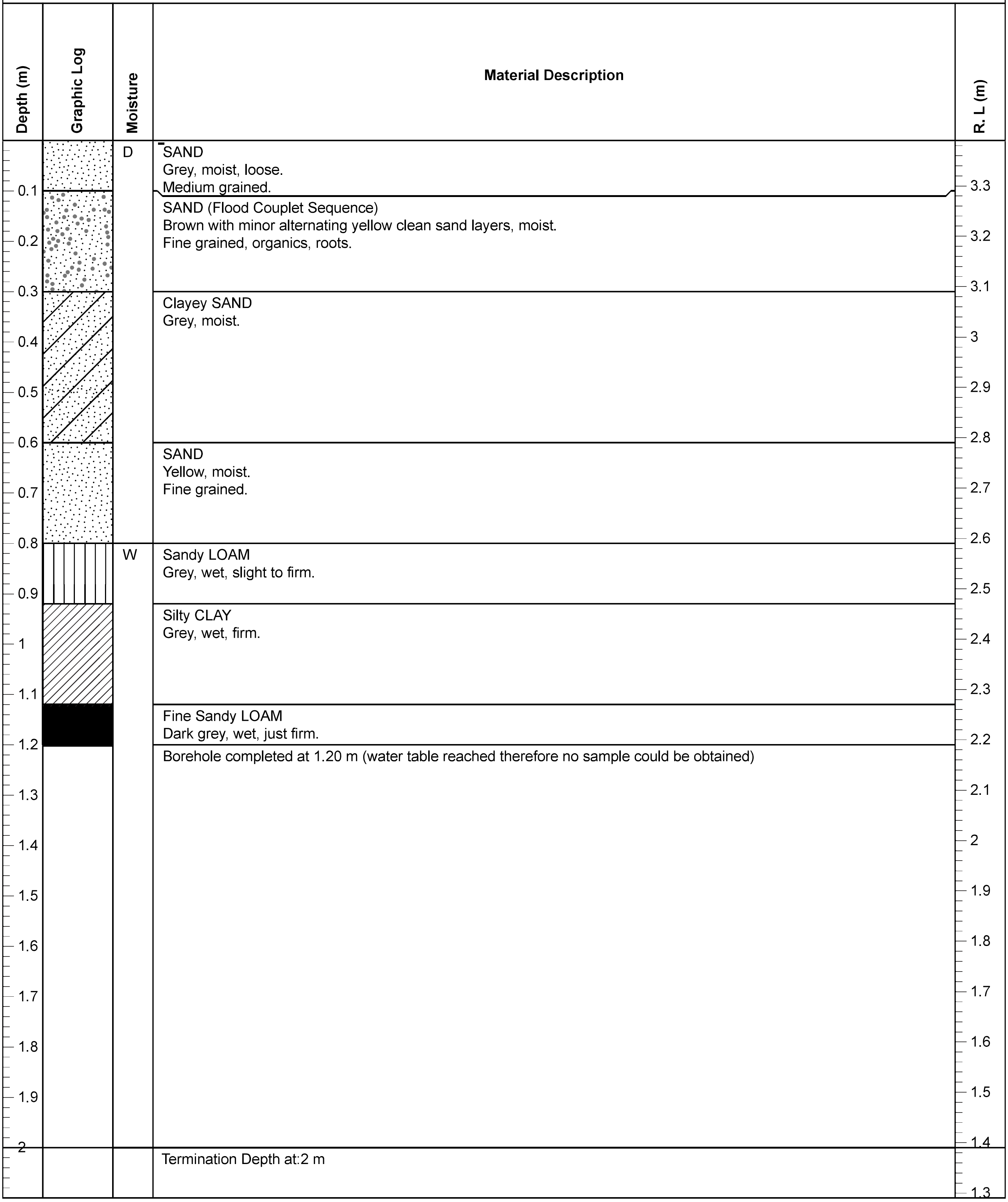
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

COORDINATES 338282.4, 6267904
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.39

COMMENTS Sample site top of bank (right) flood runner.

LOGGED BY RMH



Moisture	Material Description
D	SAND Grey, moist, loose. Medium grained.
	SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Fine grained, organics, roots.
	Clayey SAND Grey, moist.
	SAND Yellow, moist. Fine grained.
W	Sandy LOAM Grey, wet, slight to firm.
	Silty CLAY Grey, wet, firm.
	Fine Sandy LOAM Dark grey, wet, just firm.
	Borehole completed at 1.20 m (water table reached therefore no sample could be obtained)
	Termination Depth at:2 m

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HAND AUGER LOG XS02-HA01

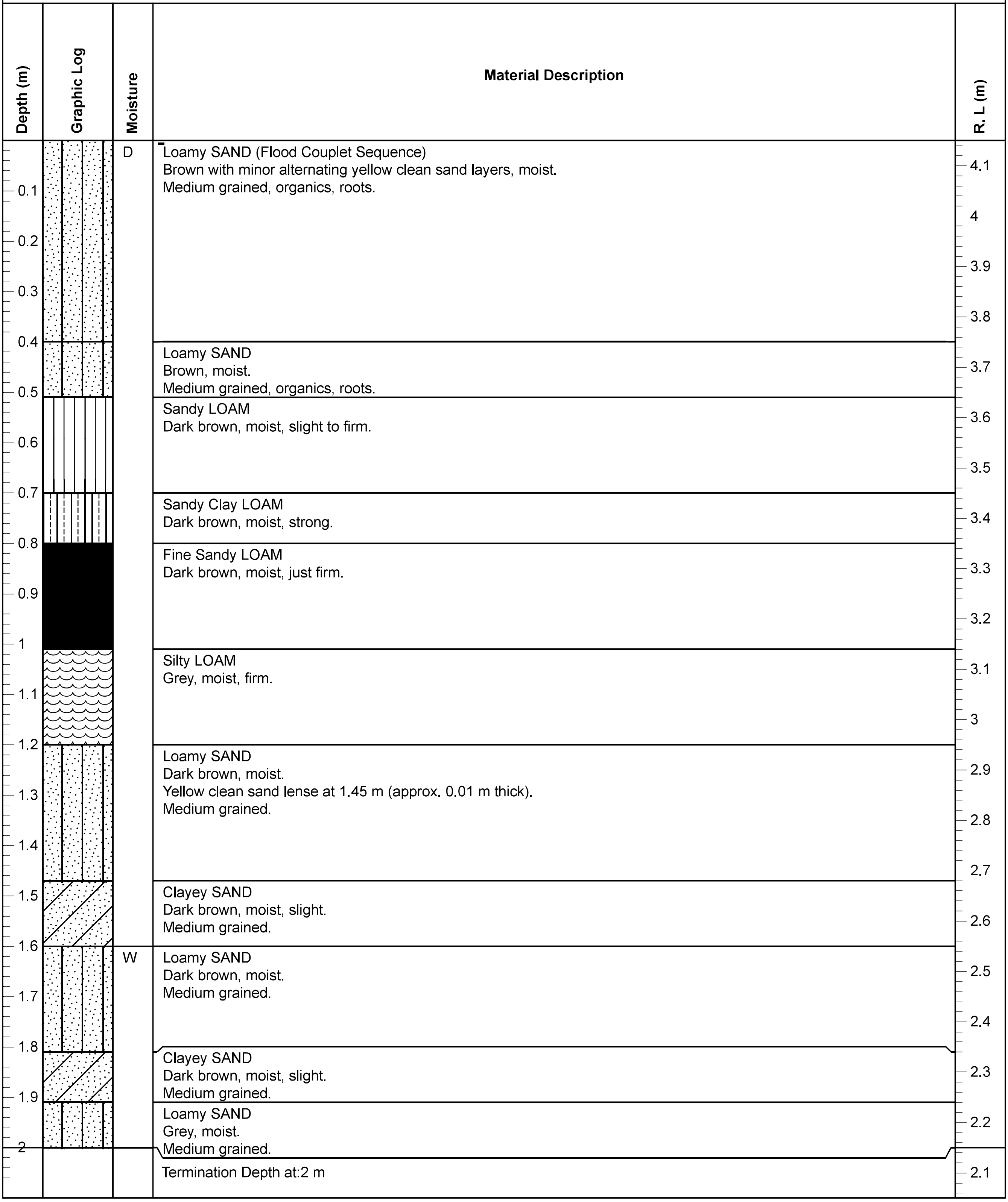
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 27/11/2018
TOTAL DEPTH 2

COORDINATES 338219.6, 6267790
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 4.15

COMMENTS Top of Bank (right)

LOGGED BY RMH



Moisture	Material Description
D	Loamy SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained, organics, roots.
	Loamy SAND Brown, moist. Medium grained, organics, roots.
	Sandy LOAM Dark brown, moist, slight to firm.
	Sandy Clay LOAM Dark brown, moist, strong.
	Fine Sandy LOAM Dark brown, moist, just firm.
	Silty LOAM Grey, moist, firm.
	Loamy SAND Dark brown, moist. Yellow clean sand lense at 1.45 m (approx. 0.01 m thick). Medium grained.
	Clayey SAND Dark brown, moist, slight. Medium grained.
W	Loamy SAND Dark brown, moist. Medium grained.
	Clayey SAND Dark brown, moist, slight. Medium grained.
	Loamy SAND Grey, moist. Medium grained.

Termination Depth at:2 m

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Soil Conservation Service

HAND AUGER LOG XS02-HA02

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 27/11/2018
TOTAL DEPTH 2

COORDINATES 338206, 6267799
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 4.01

COMMENTS

LOGGED BY RMH

Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
0.1 0.2 0.3 0.4 0.5 0.6		D	Loamy SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained, organics, roots.	4 3.9 3.8 3.7 3.6 3.5 3.4
0.7			SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained, organics, roots.	3.3
0.8 0.9			Sandy LOAM Grey, moist, slight to just firm.	3.2 3.1
1 1.1			Clayey SAND Grey, wet, slight. Medium grained.	3 2.9
1.2 1.3 1.4			Sandy LOAM Brown, moist, slight to just firm.	2.8 2.7 2.6
1.5		W	Loamy SAND Grey, moist. Medium grained.	2.5
1.6 1.7 1.8			Fine Sandy LOAM Dark grey, wet, Firm.	2.4 2.3 2.2
1.9			Sandy LOAM Dark brown, wet, slight to just firm.	2.1
2			Termination Depth at:2 m	2

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HAND AUGER LOG XS02-HA03

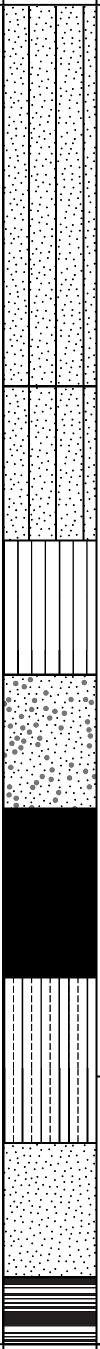
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 27/11/2018
TOTAL DEPTH 2

COORDINATES 338201.5, 6267802
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.92

COMMENTS

LOGGED BY RMH



Depth (m)	Moisture	Material Description	R. L (m)
0.1 0.2 0.3 0.4 0.5	D	Loamy SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained, organics, roots.	3.9 3.8 3.7 3.6 3.5 3.4
0.6 0.7		Loamy SAND Brown, moist. Medium grained.	3.3 3.2
0.8 0.9		Sandy LOAM Brown, moist, slight to just firm. Charcoal inclusions throughout.	3.1 3
1 1.1		SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained.	2.9 2.8
1.2 1.3 1.4		Fine Sandy LOAM Dark grey, moist, firm.	2.7 2.6 2.5
1.5 1.6	W	Sandy Clay LOAM Dark Brown, moist, strong.	2.4 2.3
1.7 1.8		SAND Dark grey, wet. Medium grained.	2.2 2.1
1.9		Light CLAY Dark brown, wet, firm to strong.	2
2		Termination Depth at:2 m	1.9

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Page 1 of 1

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HAND AUGER LOG XS02-HA04

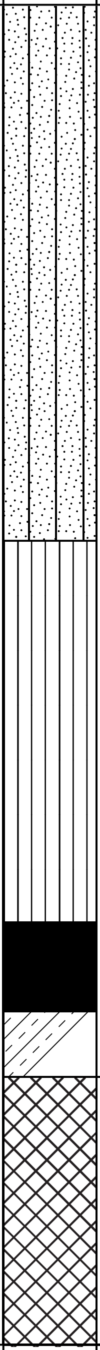
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 27/11/2018
TOTAL DEPTH 2

COORDINATES 338195.8, 6267807
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.64

COMMENTS

LOGGED BY RMH



Depth (m)	Moisture	Material Description	R. L (m)
0.1 0.2 0.3 0.4 0.5 0.6 0.7	D	Loamy SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained, organics, roots.	3.6 3.5 3.4 3.3 3.2 3.1 3 2.9
0.8 0.9 1 1.1 1.2 1.3		Sandy LOAM Grey, moist, slight to just firm.	2.8 2.7 2.6 2.5 2.4 2.3
1.4		Fine Sandy LOAM Dark grey, moist, firm.	2.2
1.5		Sandy CLAY Dark grey, moist, firm to strong.	2.1
1.6 1.7 1.8 1.9	W	Silty Clay LOAM Black, wet, firm.	2 1.9 1.8 1.7
2		Termination Depth at:2 m	1.6

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HAND AUGER LOG XS03-HA01

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 27/11/2018
TOTAL DEPTH 2

COORDINATES 337963.8, 6267711
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.44

COMMENTS

LOGGED BY RMH

Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
0.1 0.2 0.3 0.4	▨	D	Silty CLAY Dark brown, moist, firm. Organics, roots to approx. 0.1 m	3.4 3.3 3.2 3.1 3
0.5 0.6	▨		Sandy CLAY Dark brown, moist, firm. Some coarse sand grains throughout.	2.9 2.8
0.7 0.8	▨		Silty CLAY Dark grey, moist, firm.	2.7 2.6
0.9 1	▨	W	Sandy CLAY Dark brown, moist, firm.	2.5 2.4
1.1	░		SAND Dark brown, wet. Medium grained.	2.3
1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9			Borehole completed at 1.20 m (water table reached therefore no sample could be obtained)	2.2 2.1 2 1.9 1.8 1.7 1.6 1.500
2			Termination Depth at:2 m	1.400

Disclaimer This bore log is intended for environmental not geotechnical purposes.

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HAND AUGER LOG XS03-HA02

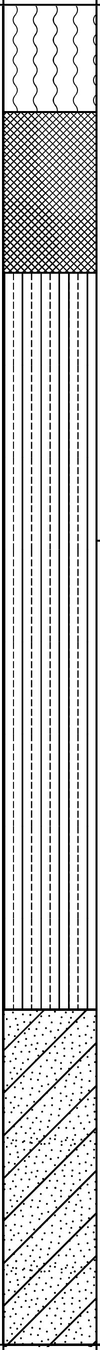
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 3/12/2018
TOTAL DEPTH 2

COORDINATES 337957.5, 6267692
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.76

COMMENTS Floodplain (right) - boggy/swampy area 70m from base of road batter.

LOGGED BY RMH



Depth (m)	Moisture	Material Description	R. L (m)
0.1	D	LOAM (Top Soil) Brown, dry, spongy to firm. Organics, roots.	3.7
0.2		Clay LOAM Brown, moist, strong. Charcoal inclusions throughout.	3.6
0.3			3.5
0.4		Sandy Clay LOAM Dark grey, moist to wet, firm.	3.4
0.5			3.3
0.6			3.2
0.7			3.1
0.8	W		3
0.9			2.9
1			2.8
1.1			2.7
1.2			2.6
1.3			2.5
1.4			2.4
1.5		Clayey SAND Dark grey, wet. Medium grained.	2.3
1.6			2.2
1.7			2.1
1.8			2
1.9			1.9
2		Termination Depth at:2 m	1.8
			1.7

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HAND AUGER LOG XS03-HA03

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 3/12/2018
TOTAL DEPTH 2

COORDINATES 337949.8, 6267670
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 4.64

COMMENTS Top of Bank (Left)

LOGGED BY RMH

Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
0.1		D	Sandy LOAM Light brown, moist, slight to just firm. Organics, roots.	4.6 4.5
0.2 0.3 0.4 0.5 0.6			Loamy SAND Brown, moist. Fine grained.	4.4 4.3 4.2 4.1 4
0.7			SAND Yellow, moist. Medium grained.	3.9
0.8 0.9 1			Loamy SAND (Flood Couplet/Overbank Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained.	3.8 3.7 3.6
1.1 1.2 1.3			Loamy SAND Brown, moist. Fine grained.	3.5 3.4
1.4			SAND Yellow, moist. Medium grained.	3.3
1.5 1.6 1.7 1.8 1.9		W	Loamy SAND Grey, moist to wet. Fine grained.	3.2 3.1 3 2.9 2.8 2.7
2			Termination Depth at:2 m	2.6

produced by ESlog.ESdat.net on 10 Jan 2019

Soil Conservation Service

HAND AUGER LOG XS03-HA04

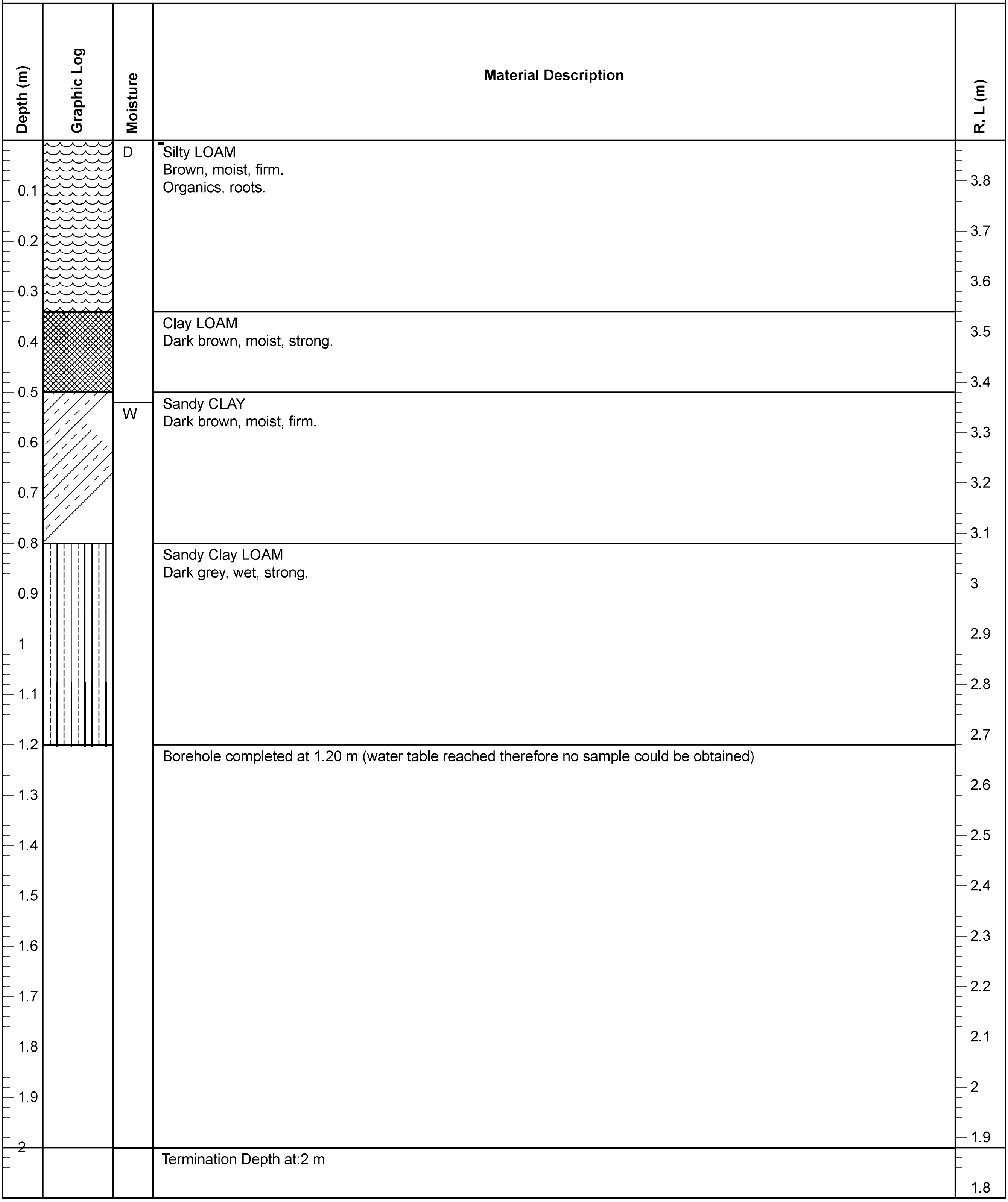
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 3/12/2018
TOTAL DEPTH 2

COORDINATES 337943, 6267651
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.88

COMMENTS Low lying swampy area 70 m from toe of batter.

LOGGED BY RMH



Silty LOAM
Brown, moist, firm.
Organics, roots.

Clay LOAM
Dark brown, moist, strong.

Sandy CLAY
Dark brown, moist, firm.

Sandy Clay LOAM
Dark grey, wet, strong.

Borehole completed at 1.20 m (water table reached therefore no sample could be obtained)

Termination Depth at:2 m

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NSW GOVERNMENT | **Soil Conservation Service**

HAND AUGER LOG XS07-HA01

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 4/12/2018
TOTAL DEPTH 2

COORDINATES 337268.1, 6267322
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 6.55

COMMENTS

LOGGED BY RMH

Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
0.1		D	Silty LOAM Dark brown, moist, firm. Organics, roots.	6.5
0.2			Disturbed Material/Rubble Fill (brick, gravel) Reddish brown, moist, non cohesive.	6.4
0.3			Silty Clay LOAM Dark brown, moist to wet, firm. Large charcoal inclusions at 1.04 m (10 to 20 mm length).	6.3
0.4				6.2
0.5				6.1
0.6				6
0.7				5.9
0.8				5.8
0.9		W		5.7
1				5.6
1.1				5.5
1.2				5.4
1.3			Borehole completed at 1.20 m (water table reached therefore no sample could be obtained)	5.3
1.4				5.2
1.5				5.1
1.6				5
1.7				4.9
1.8				4.8
1.9				4.7
2				4.6
			Termination Depth at:2 m	4.5

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Soil Conservation Service

HAND AUGER LOG XS07-HA02

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 4/12/2018
TOTAL DEPTH 2

COORDINATES 337281.5, 6267319
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 7.09

COMMENTS

LOGGED BY RMH

Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
0.1 0.2 0.3 0.4 0.5		D	SAND Yellow, dry, loose. Fine grained, organics, roots.	7 6.9 6.8 6.7 6.6
0.6			Sandy LOAM Brown, moist, slight to just firm. Fine grained.	6.5
0.7			Silty Clay LOAM Brown, moist, strong.	6.4
0.8			Loamy SAND Yellow/brown, moist.	6.3
0.9 1 1.1			LOAM Dark brown, moist, spongy to firm.	6.2 6.1 6
1.2			Clayey SAND Brown, moist, slight. Fine grained.	5.9
1.3			Sandy LOAM Grey/brown, moist, slight to just firm.	5.8
			Charcoal Layer	
1.4 1.5 1.6 1.7 1.8 1.9		W	Sandy CLAY Dark grey, wet, firm. Pebble sized inclusions at 1.5 m	5.7 5.6 5.5 5.4 5.3 5.2
2			Termination Depth at:2 m	5.1 5

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NSW GOVERNMENT | Soil Conservation Service

HAND AUGER LOG XS07-HA03

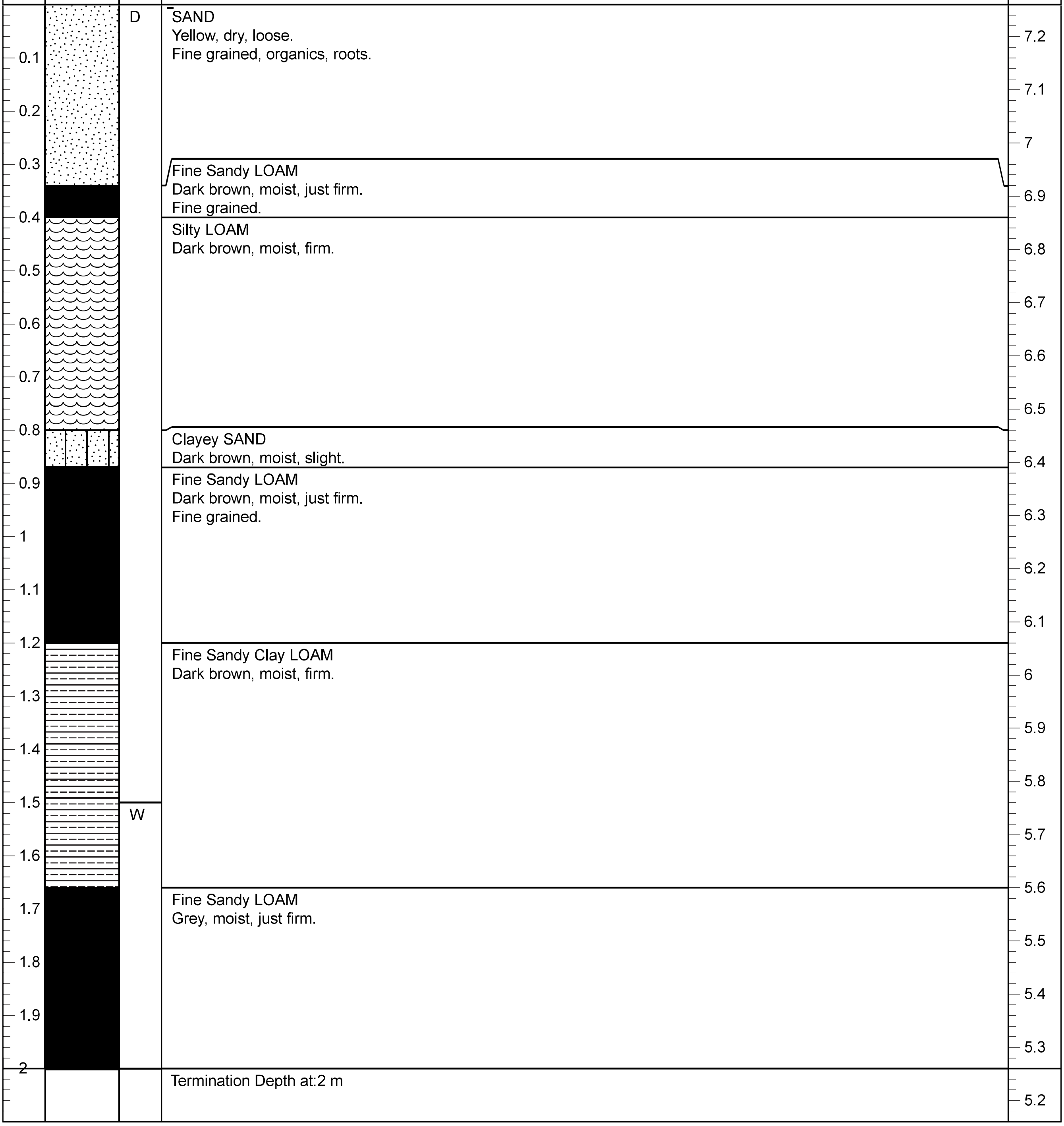
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 4/12/2018
TOTAL DEPTH 2

COORDINATES 337292.8, 6267318
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 7.26

COMMENTS Top of Bank (left)
LOGGED BY RMH

Depth (m) | **Graphic Log** | **Moisture** | **Material Description** | **R. L (m)**



SAND
Yellow, dry, loose.
Fine grained, organics, roots.

Fine Sandy LOAM
Dark brown, moist, just firm.
Fine grained.

Silty LOAM
Dark brown, moist, firm.

Clayey SAND
Dark brown, moist, slight.

Fine Sandy LOAM
Dark brown, moist, just firm.
Fine grained.

Fine Sandy Clay LOAM
Dark brown, moist, firm.

Fine Sandy LOAM
Grey, moist, just firm.

Termination Depth at:2 m

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Soil Conservation Service

HAND AUGER LOG XS08-HA01

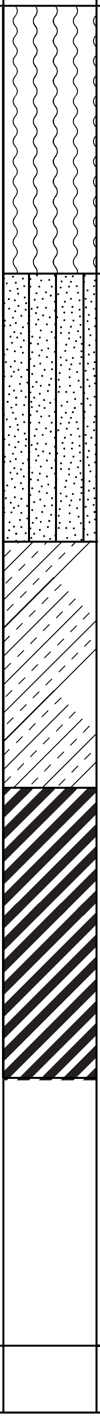
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

COORDINATES 338141.1, 6267724
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 3.46

COMMENTS Sample site located transition between floodplain to swamp environment.

LOGGED BY RMH



Depth (m)	Moisture	Material Description	R. L (m)
0.1 0.2 0.3	D	LOAM (Top Soil) Brown, moist, spongy to firm. Fine grained, organics, roots, charcoal inclusions at 0.20 m.	3.4 3.3 3.2 3.1
0.4 0.5 0.6 0.7	W	Sandy Clay LOAM Dark brown to grey, wet, strong. Medium grained (sand component).	3 2.9 2.8 2.7
0.8 0.9 1 1.1		Sandy CLAY Grey, wet.	2.6 2.5 2.4 2.3
1.2 1.3 1.4 1.5		Heavy CLAY Yellow / grey, very strong.	2.2 2.1 2 1.9
1.6 1.7 1.8 1.9		Refusal at 1.6 m.	1.8 1.7 1.6 1.500
2		Termination Depth at:2 m	1.400

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Soil Conservation Service

HAND AUGER LOG XS08-HA02

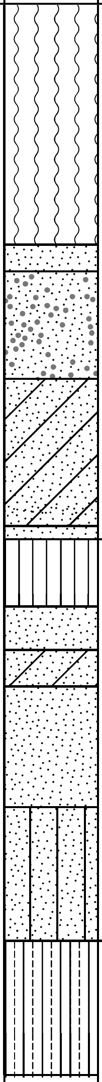
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

COORDINATES 338145.3, 6267715
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 4.13

COMMENTS

LOGGED BY RMH



Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
0.1 0.2		D	LOAM (Top Soil) Brown, moist, spongy to firm. Fine grained, organics, roots.	4.1 4 3.9
0.3			SAND Yellow, moist. Medium grained.	3.8
0.4 0.5			SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained.	3.7 3.6
0.6			Clayey SAND Black, moist, loose. Medium grained.	3.5
0.7			SAND Yellow, moist, loose. Medium grained, sand lense.	3.4
0.8			Sandy LOAM Dark brown, moist, slight to just firm.	3.3
0.9 1			SAND Light brown, moist, loose. Medium grained.	3.2
1.1			Clayey SAND Dark brown, moist. Medium grained.	3.1 3
1.2			SAND Light brown, moist, loose. Medium grained.	2.9
1.3			Loamy SAND Brown, moist. Fine grained.	2.8
1.4 1.5		W	Sandy Clay LOAM Brown, wet, strong.	2.7 2.6
1.6 1.7 1.8 1.9			Borehole completed at 1.60 m (water table reached therefore no sample could be obtained)	2.5 2.4 2.3 2.2
2			Termination Depth at:2 m	2.1

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HAND AUGER LOG XS08-HA03

PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

COORDINATES 338148.8, 6267706
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 4.26

COMMENTS Top of Bank (left)

LOGGED BY RMH

Depth (m)	Graphic Log	Moisture	Material Description	R. L (m)
0.1 0.2	▥	D	Sandy LOAM (Top Soil) Brown, moist, slight to just firm. Fine grained, organics, roots.	4.2 4.1
0.3 0.4 0.5 0.6 0.7 0.8 0.9 1	░		SAND Yellow, moist. Fine grained.	4 3.9 3.8 3.7 3.6 3.5 3.4 3.3 3.2
1.1 1.2	▥		Sandy LOAM Brown, moist. Fine grained.	3.1
1.3	░		SAND Brown, moist.	3
1.4	■		Fine Sandy LOAM Brown, moist, just firm. Fine grained.	2.9 2.8
1.5 1.6 1.7 1.8	▨	W	Clayey SAND Grey, wet. Fine grained.	2.7 2.6 2.5 2.4
1.9 2	░		SAND Grey, wet. Fine grained.	2.3
			Termination Depth at:2 m	2.2

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Soil Conservation Service

HAND AUGER LOG XS08-HA04

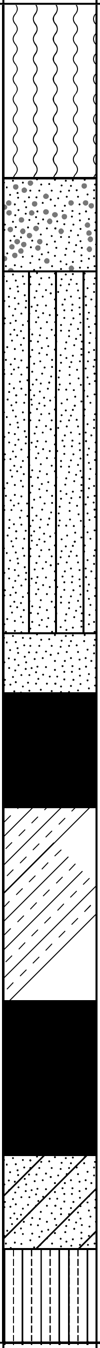
PROJECT NUMBER SCS3039
PROJECT NAME Middle Creek Sand Extent
CLIENT Northern Beaches Council
ADDRESS Wakehurst Parkway, Oxford Falls NSW

DRILLING DATE 5/12/2018
TOTAL DEPTH 2

COORDINATES 338155.5, 6267694
COORD SYS GDA 94 / MGA Zone 56
HEIGHT DATUM AHD
SURFACE RL 4.41

COMMENTS Top of Bank (right)

LOGGED BY RMH



Depth (m)	Moisture	Material Description	R. L (m)
0.1 0.2	D	LOAM (Top Soil) Brown, moist, spongy to firm. Fine grained, organics, roots, visible sand grains top 0.02m	4.5 4.4 4.3
0.3		SAND (Flood Couplet Sequence) Brown with minor alternating yellow clean sand layers, moist. Medium grained.	4.2
0.4 0.5 0.6 0.7 0.8 0.9		Loamy SAND Brown, moist.	4.1 4 3.9 3.8 3.7
1		SAND Yellow, moist. Fine grained, medium to large pebble inclusions.	3.6 3.5
1.1		Fine Sandy LOAM Brown, moist, firm.	3.4
1.2 1.3 1.4		Sandy CLAY Dark brown, moist, firm. Fine grained.	3.3 3.2 3.1
1.5 1.6 1.7		Fine Sandy LOAM Dark brown, moist, firm.	3 2.9 2.8
1.8		Clayey SAND Brown, moist, slight.	2.7
1.9 2		Sandy Clay LOAM Dark grey, moist, strong.	2.6
		Termination Depth at:2 m	2.5

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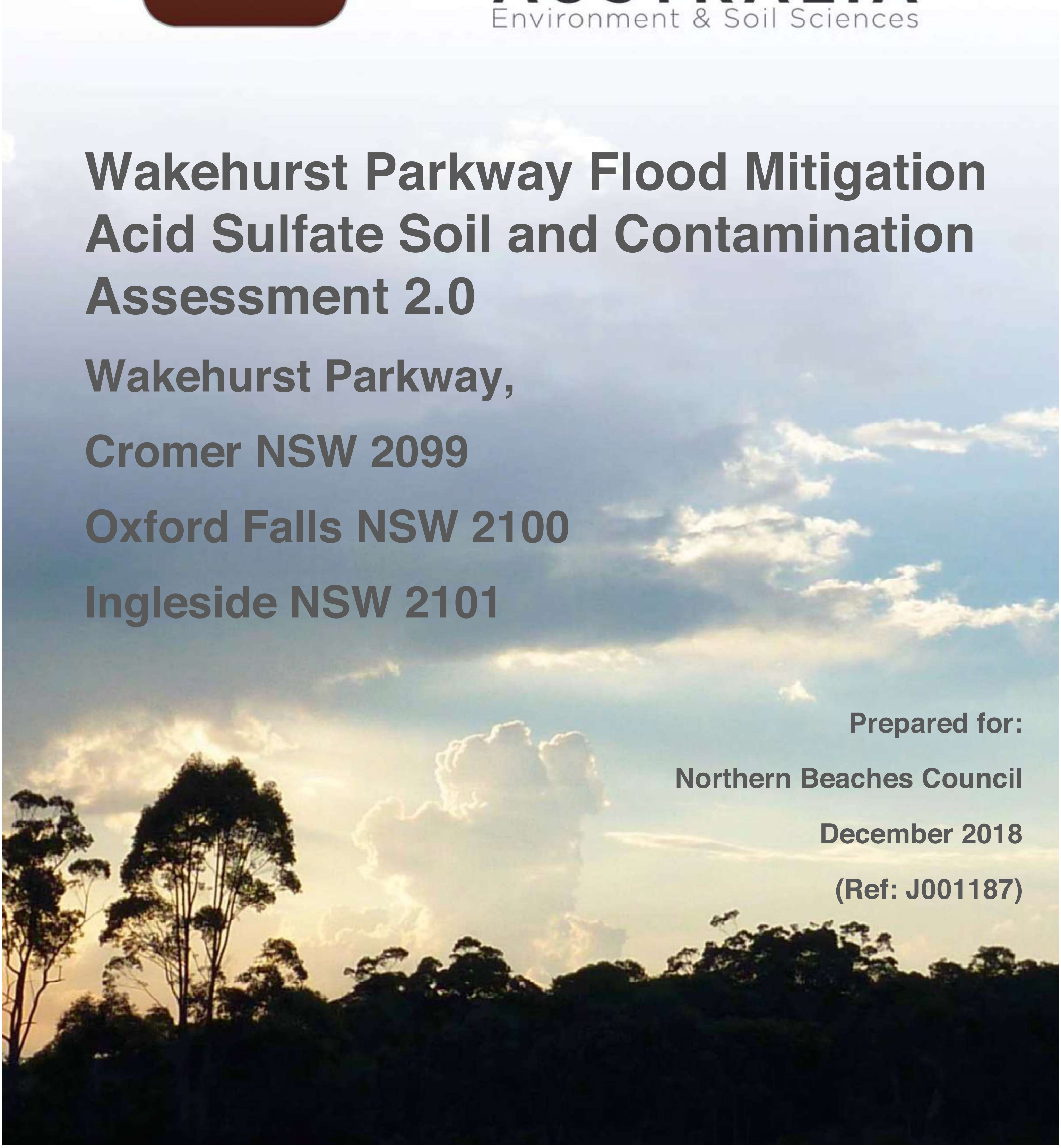
APPENDIX G – Soil Contamination Report



Wakehurst Parkway Flood Mitigation Acid Sulfate Soil and Contamination Assessment 2.0

Wakehurst Parkway,

Cromer NSW 2099

Oxford Falls NSW 2100

Ingleside NSW 2101

Prepared for:

Northern Beaches Council

December 2018

(Ref: J001187)

Document Record

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0.3	S Jamieson	Changes and updates	Internal	7/11/2018	
1.0	R Jacka	Final changes and authorisation	Internal	7/11/2018	
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TABLE OF CONTENTS

DOCUMENT TABLES IN TEXT

APPENDICES

ABBREVIATIONS

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ASC NEPM 2013	Assessment of Site Contamination National Environment Protection (Assessment of Site Contamination) Measure 1999 (April 2013), NEPC 2013, Canberra.
ASS	Acid Sulfate Soils
AASS	Actual Acid Sulfate Soils
BaP	Benzo(a)pyrene
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
BTEXN	Benzene, Toluene, Ethylbenzene, Xylenes and Naphthalene
CLM	Contaminated Land Management Act
COC	Chain of Custody
CPAHs	Carcinogenic Polycyclic Aromatic Hydrocarbons
DEC	Department of Environment and Conservation NSW
DECC	Department of Environment and Climate Change NSW
DECCW	Department of Environment, Climate Change and Water NSW
DP	Deposited Plan
EILs	Ecological Investigation Levels.
ENM	Excavated Natural Material
EPA	NSW Environmental Protection Authority
ESLs	Ecological Screening Levels
GILs	Groundwater Investigation Levels
HILs	Health Investigation Levels
HSLs	Health Screening Levels
LGA	Local Government Area
LOR	Limit of Reporting
MAHs	Monocyclic Aromatic Hydrocarbons
MCMS	Material Compliance Management System
NATA	The National Association of Testing Authorities
NEPM	National Environment Protection Measure
NHMRC	National Health Medical Research Council
NSW	New South Wales
OCP	Organochlorine Pesticides
OPP	Organophosphate Pesticides
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PCOC	Potential Contaminants of Concern
PASS	Potential Acid Sulfate Soils
PID	Photo Ionisation Detector
POEO	Protection of the Environment Operation
PPM	Parts Per Million
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
RPD	Relative Percent Difference
RSL	Regional Screening Levels
SAC	Site Assessment Criteria
SESL	SESL Australia Pty Limited
SMF	Synthetic Mineral Fibre
SPOCAS	Suspension Peroxide Oxidation – Combined Acidity and Sulfate
SVOC	Semi-Volatile Organic Compounds
TEQ	Toxic Equivalence Quotient
TCLP	Toxicity Contaminant Leaching Procedure
TPH	Total Petroleum Hydrocarbons
TRH	Total Recoverable Hydrocarbon
TRH F1	Total Recoverable Hydrocarbon C6-C10 minus BTEX
UCL	Upper Confidence Limit
VENM	Virgin Excavated Natural Material
VOC	Volatile Organic Compounds
VSAQP	Validation Sampling, Analysis and Quality Plan

1 EXECUTIVE SUMMARY

SESL Australia Pty Limited (SESL) was engaged by Northern Beaches Council to conduct an Acid Sulfate Soil (ASS) and Contamination Investigation at the site of expected soil disturbance associated with the proposed flood mitigation construction and earthworks. This investigation included the assessment of soils within the vicinity of six (6) proposed culvert upgrades and creek sediment removal, adjacent to Wakehurst Parkway, within the suburbs of Cromer (NSW 2099), Ingleside (NSW 2101) and Oxford Falls (NSW 2100).

The environmental assessment works undertaken during this ASS Investigation comprised of the following:

- Visual inspection of the locations of proposed site works on 3/10/2018, 26/10/2018 and 31/10/2018;
- Collection and analysis of 19 soil samples for sPOCAS analysis;
- Collection and analysis of 22 soil samples for acid sulfate screens;
- Collection and analysis of 33 soil samples for contamination analysis;
- Preparation of this report detailing methodologies used during this investigation, results, management strategies and conclusions regarding the acid sulfate soil risk associated with the proposed development at the site.

Investigative work was conducted in accordance with the following applicable guidelines:

- Acid Sulfate Soils Manual (NSW Acid Sulfate Soils Management Advisory Committee, 1998); and
- Assessing and Managing Acid Sulfate Soils - Guidelines for and Management in NSW Coastal Areas (EPA, 1995).
- NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014);

This report is based on the field data obtained from the samples collected from the proposed inlet and outlet locations of six culverts in the investigation area and material collected from the subject sediments at Middle Creek (The Bends).

Based on the findings of this assessment undertaken by SESL, the soils within the proximity of some of the proposed culvert locations are considered to be potential and actual acid sulfate soil. SESL recommends that the proposed excavation works must be managed under the site-specific Acid Sulfate Soil Management Plan (ASSMP).

Based on limited assessment and in accordance with the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)*, the soils proposed for excavation within the proximity of the culverts meet the criteria for General Solid Waste. In accordance with landfill's Environmental Protection Licenses (EPL), the material is **not** considered suitable for recycling due to elevated benzo(a)pyrene, nickel and lead.

Soils proposed for excavation within the subject area of Middle Creek (The Bends) are considered to not be Acid Sulfate Soils, and do not require management under an ASSMP. SESL suggests that the observed acidity is likely the result of extensive organic matter within the subject materials, and not the result of present sulfur.

In accordance with the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)*, all samples collected from within creek sediments meet the criteria for General Solid Waste. However, based on the results of this limited assessment, SESL recommends that the subject soils proposed for excavation will meet the requirements for classification as Excavated Natural Material (ENM), and that consideration should be given to further assessment for the classification of these soils as ENM, to reduce the cost of offsite disposal.

2 INTRODUCTION

SESL Australia Pty Limited (SESL) was engaged by Northern Beaches Council to conduct an Acid Sulfate Soil (ASS) and Contamination Investigation at the site of expected soil disturbance associated with the proposed flood mitigation construction and earthworks. This investigation included the assessment of soils within the vicinity of six (6) proposed culvert upgrades and creek sediment removal, adjacent to Wakehurst Parkway, within the suburbs of Cromer (NSW 2099), Ingleside (NSW 2101) and Oxford Falls (NSW 2100).

SESL understands that the proposed works at the site involve the excavation of site soils for the construction and/or redevelopment of culverts under Wakehurst Parkway, and the excavation and removal of sediments within a stretch of Middle Creek that have built up over a significant period. This Acid Sulfate Soil and Contamination Assessment is limited to the portion of the site affected by the proposed excavation works for the proposed culverts and sediment within Middle Creek. The site locality and layout is provided in Figure 1 & 2 of this report.

2.1 PURPOSE AND SCOPE

The environmental assessment works undertaken during this investigation comprised of the following:

- Visual inspection of the site on 3/10/2018, 26/10/2018 and 31/10/2018;
- Collection of soil samples from the proposed maximum excavation depth from proposed inlet and outlet locations (where accessible) of six (6) culverts;
- Collection of sediment samples from Middle Creek;
- Analysis of 26 soil samples for sPOCAS analysis;
- Analysis of 22 soil samples for acid sulfate screen;
- Analysis of 33 soil samples for contamination analysis; and
- Preparation of this report detailing methodologies used during this investigation, results, management strategies and conclusions regarding the acid sulfate soil and contamination risk associated with the proposed works for the culverts at this site.

Investigative work was conducted in accordance with the following applicable guidelines:

- Acid Sulfate Soils Manual (NSW Acid Sulfate Soils Management Advisory Committee, 1998); and
- Assessing and Managing Acid Sulfate Soils - Guidelines for and Management in NSW Coastal Areas (EPA, 1995); and
- NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014).

2.2 DEFINITION OF ACID SULFATE SOILS

Acid sulfate soil is the common name given to naturally occurring sediments and soils containing iron sulphides (principally iron sulphide or iron disulphide or their precursors). The exposure of the sulfide in these soils to oxygen by drainage or excavation leads to the generation of sulfuric acid.

Acid sulfate soils (ASS) include actual acid sulfate soils or potential acid sulfate soils. Actual and potential acid sulfate soils are often found in the same profile, with actual acid sulfate soils generally overlying potential acid sulfate soil horizons.

Actual acid sulfate soils are soils containing highly acidic soil layers caused by the oxidation of soils that are rich in iron sulphides. This oxidation produces acidity in excess of the soil's capacity to neutralise it and results in soils of pH of 4 or less. These soils can usually be identified by the presence of pale yellow mottles and coatings of jarosite.

Potential acid sulfate soils (PASS) are soils that contain iron sulphides that have not been exposed to air and oxidised. The field pH of these soils in the undisturbed state is 4 or more and is commonly neutral or slightly alkaline. However, they pose a considerable environmental risk when disturbed, as they will become more acidic when exposed to air and oxidised.

3 SITE DESCRIPTION

3.1 SITE LOCATION

The location of the assessment was limited to select areas, including six (6) culverts and a section of Middle Creek. Five (5) of the six (6) culverts assessed are located along a 4 km stretch of Wakehurst Parkway, and are accessible from the road verge either side of the road. The final culvert assessed is located and accessible from within the Sydney Academy of Sport and Recreation. The section of Middle Creek subject to this investigation lies runs parallel to Wakehurst Parkway, on the northern side of the road. Refer to Figure 1 for site layout.

3.2 SITE IDENTIFICATION

The following details describe the portion of land subjected to the investigation:

Table 1 – Site Identification

Site Address	Wakehurst Parkway Cromer (NSW 2099), Ingleside (NSW 2101) and Oxford Falls (NSW 2100)
Local Government Area	Northern Beaches Council
Current Zoning	SP2 Infrastructure, RE1 Public Recreation, SP1 Special Activities
Distance from Sydney CBD	Approximately 17 km North of the Sydney CBD
Geographical Coordinates	33°43'00"S 151°16'00"E
Site Elevation	Approximately 0-75 m AHD

3.3 SITE LAYOUT AND INFRASTRUCTURE

The site layout and location of this investigation area can be viewed in Figure 1. The site is along a road corridor on land owned or managed by Northern Beaches Council (formerly Warringah Council before amalgamation). Near the northern portion of the site, there is a large rural residential property. Wakehurst Parkway runs through bushland and is adjacent to Middle Creek. The eastern border of the investigation areas is marked by the Sydney Academy of Sport and Recreation and the south-western boundary is marked by Oxford Falls.

4 ENVIRONMENTAL SETTING

4.1 DESCRIPTION OF GEOLOGY

The *Soil Landscapes of the Sydney 1:100 000 Sheet Map (Chapman and Murphy, 1989*) identifies the majority of the site to be within the Deep Creek Alluvial Landscape Group, the Hawkesbury Colluvial Landscape Group, the Oxford Falls Transferral Landscape Ground and Disturbed Terrain.

The majority of the investigation area is situated within the Deep Creek Landscape Group, which typically consists of level to gently undulating alluvial floodplain. Soils are deep on well-drained terraces with siliceous sands on current floodplain and humus podzols in low lying areas. Limitations associated with this soil landscape include flooding hazard, extreme soil erosion hazard, sedimentation hazard, localised very low fertility and permanently high watertables. This soil landscape was observed across the site as well as a mix of material collecting in inlet areas including some anthropogenic foreign materials.

The Oxford Falls Landscape Group typically consists of moderately deep to deep earthy sands, yellow earths, siliceous sands on slopes, deep leached sands, podzols and grey earths on valley floors. Limitations of this soil landscapes very high soil erosion hazard, perched watertables and swamps, highly permeable soil', very low to low soil fertility and localised rock outcrop.

Disturbed terrain has various characteristic and associated limitations which are largely dependent on the nature of the disturbed soil or fill.

4.2 DESCRIPTION OF HYDROLOGY

A groundwater bore search was undertaken using the groundwater database under Office of Water, Department of Primary Industries (http://allwaterdata.water.nsw.gov.au). Five groundwater bores were located within a one-kilometre radius of the site. All five bores are registered for domestic use. The following domestic bores registered are within approximately one kilometre of the proposed culvert locations:

- GW032798 (SWL: N/A; Intended purpose: Domestic)
- GW029540 (SWL: N/A; Intended purpose: Stock/domestic)
- GW035940 (SWL: N/A; Intended purpose: Irrigation)
- GW108976 (SWL: 30m; Intended purpose: Stock/domestic)
- GW108250 (SWL: 21m; Intended purpose: Recreation (groundwater)

4.3 DESCRIPTION OF WORKS

SESL has been advised that the proposed works include the significant earth works associated with the upgrading and construction of six (6) culverts along Wakehurst Parkway, as well as the excavation and offsite disposal of sediment build-up within the subject section of Middle Creek, adjacent to Wakehurst parkway.

4.4 ACID SULFATE SOIL OCCURRENCE

The ASS maps identify 5 classes of land, with Class 1 being the highest at risk of ASS. The Warringah Local Environment Plan (LEP) 2011 Acid Sulfate Soil Map indicates the site to be within Class 2, Class 3 and Class 5 risk areas. The ASS maps further identify the types of work likely to present an environmental risk if undertaken. If these types of works are proposed, then further investigation is required to determine ASS impacts, as shown in the **Error! Reference source not found.** below.

Table 2 – Acid Sulfate Soil Classes Present at the Site

Class	Works
2	▪ Works below natural ground surface Works by which the water table is likely to be lowered
3	▪ Works beyond 1 meter below natural ground surface ▪ Works by which the water table is likely to be lowered beyond 1 meter below natural ground surface
5	▪ Works within 500 meters of adjacent Class 1, 2, 3 or 4 land which are likely to lower the water table below 1 meter AHD on adjacent Class 1, 2, 3 or 4 land

SESL understands excavation works below ground surface are required as part of the proposed works, therefore the requirement for assessment is triggered. See LEP Acid Sulfate Risk Map in Appendix B (LEP map 7).

The Acid Sulfate Soils Management Advisory Committee (ASSMAC) Guidelines 1998 considers the following geomorphic conditions when determining the ASS risk status of a given area:

- Sediments of recent geological age (Holocene) ~ 6000 to 10,000 years old;
- Soil horizons less than 5m AHD (Australian Height Datum);
- Marine or estuarine sediment and tidal lakes;
- In coastal wetlands or back swamp areas, waterlogged or scalded areas; interdune swales or coastal sand dunes;
- In areas where the dominant vegetation is mangroves, reeds, rushes and other swamp tolerant and marine vegetation such as swamp mahogany (Eucalyptus robusta), paperbark (Melaleuca quinquenervia) and swamp oak (Casuarina glauca);
- In areas identified in geological descriptions or in maps bearing sulphide minerals, coal deposits or former marine shales/ sediments; and

- Deeper older estuarine sediments >10m below the ground surface, Holocene or Pleistocene age (only an issue if deep excavation or drainage is proposed).

4.5 PROXIMITY TO LOCAL SENSITIVE ENVIRONMENTS

According to the *UPSS Regulation Sensitive Zone Map for Warringah Council* (2010), the site of the proposed works is entirely within an environmentally sensitive zone.

5 RELEVANT GUIDELINES FOR ACID SULFATE SOIL ASSESSMENT & MANAGEMENT

5.1 RELEVANT GUIDELINES

Assessment criteria will be based on the *Acid Sulfate Soils Manual* (Acid Sulfate Soils Management Advisory Committee [ASSMAC] 1998 which incorporate the following guidelines:

- The Acid Sulfate Soils Assessment Guidelines 1998;
- The Acid Sulfate Soils Planning Guidelines 1998;
- The Acid Sulfate Soils Management Guidelines 1998; and
- The Acid Sulfate Soils Laboratory Method Guidelines 1998.

The ASS Manual developed by ASSMAC provides advice on best practice in planning, assessment and management of activities in areas containing acid sulfate soils. These guidelines update and expand on the *Environmental Guidelines: Assessing and Managing Acid Sulfate Soils* issued by the EPA in 1995.

5.2 THE ACID SULFATE SOILS ASSESSMENT GUIDELINES (ASSMAC 1998)

The Acid Sulfate Soils Assessment Guidelines have been developed primarily for proponents of activities that are likely to disturb acid sulfate soils, and for councils and government authorities responsible for assessing these proposals. The guidelines recommend the adoption of best management practice in the planning, design and undertaking of activities that disturb acid sulfate soils.

The guidelines outline the following:

- How to undertake a preliminary assessment to confirm if acid sulfate soils are present on site, and if present, the likelihood of the works to disturb the soils and potential impacts of works;
- How to develop mitigation and management strategies for a particular proposal and the preparation of an acid sulfate soil management plan;
- Steps in the assessment and approval process and matters that should be included in an application for approval of works disturbing acid sulfate soils; and
- Matters that approval authorities should consider in making a decision in relation to works disturbing acid sulfate soils.

The guidelines apply to all the following activities undertaken in areas likely to affect or use coastal sediments, warrant an assessment of the risk of exposing acid sulfate soil:

- Excavation or disturbance of acid sulfate soil (i.e. roads and foundation constructions, drainage works, land forming works, flood mitigation works, dams and aquaculture ponds, sand or gravel extraction, dredging). When acid sulfate materials are being excavated, attention must be given to the excavation site as well as the location where the excavated material is placed or used;

- Lowering the water table (i.e. new drainage works, deepening existing drains, groundwater use, dams de-watering, wetlands or quarries, dredging works lowering river bed);
- Use of acid sulfate soil (i.e. aquaculture pond walls, dams, flood mitigation works, imported fill material, reclamation or foreshore works);
- Physical habitat modification for mosquito control (i.e. runnelling, drainage and selective ditching to remove water or allow predatory fish access to dial pools).

The guidelines provide the action criteria to interpret analytical results that trigger the need for a management plan based on the percentage of oxidisable sulfur for broad categories of soil types.

5.3 THE ACID SULFATE SOILS PLANNING GUIDELINES (ASSMAC 1998)

The Acid Sulfate Soils Planning Guidelines supplements Local Environmental Plans (LEP) as a key regulatory mechanism to ensure sustainable management of acid sulfate soils in the coastal zone. The zoning and development control provisions in LEPs provide councils with the opportunity to ensure that land uses are carried out in an appropriate manner and that any intensification of land use does not pose unacceptable risks to the environment.

The LEP establishes a two-stage assessment.

1. Prior to undertaking works in an area mapped as having a likely risk that acid sulfate soils are present, a person may:

- Accept that acid sulfate soils are present and proceed to preparing a development application and an acid sulfate soils management plan or;
- Undertake a Preliminary Assessment to confirm whether an acid sulfate soils management plan is required. The ASS Assessment Guidelines set out the steps in a preliminary assessment. After the person has completed the preliminary assessment and ascertained that an acid sulfate soils management plan is not required, they must present their preliminary assessment to their local council seeking agreement with their decision. If council agrees in writing that an acid sulfate soils management plan is not required, then a development application is not required. If not, then the person must submit an acid sulfate soils management plan and obtain development consent prior to undertaking the works.

2. Where required, an acid sulfate soils management plan must be prepared in accordance with the *ASS Assessment Guidelines* and is to be reviewed by both the council and the Department of Land and Water Conservation.

The Department of Land and Water Conservation has prepared Acid Sulfate Soil Risk Maps for the coastal areas in NSW that predicts the distribution of acid sulfate soils based on an understanding of the factors that led to their formation reinforced by extensive soil surveying. The Acid Sulfate Soil Risk Maps have also been converted into Acid Sulfate Soil Planning Maps for use with Local Environmental Plans.

The Acid Sulfate Soil Planning Maps establish five classes (Table 2) of land based on the probability of acid sulfate soils occurrence and the type of works that might disturb them. The five classes in the Acid Sulfate Soils Planning Maps were developed by:

- Amalgamating risk classes in the Acid Sulfate Soils Risk Maps and relating them to the expected depth of occurrence of acid sulfate soils materials based on geomorphology; in amalgamating these classes the precautionary principle was applied with a conservative estimation of expected depths;
- Matching the expected depth of occurrence of acid sulfate soil materials with the depths that works would be expected to disturb soils by excavation or reduction in water table depths; and
- Including areas marked on the Acid Sulfate Soils Risk Maps as disturbed terrain. Where disturbed terrain occurred, the likely level of the natural ground surface was determined by stereoscopic examination of air photo pairs of adjacent lands. Disturbed terrain is land where soil, or other material, has been either removed or imported to significantly change the ground surface.

Table 3 – Acid Sulfate Soil Planning Map Risk Class

Class	Works
1	▪ Any works
2	▪ Works below natural ground surface Works by which the water table is likely to be lowered
3	▪ Works beyond 1 meter below natural ground surface ▪ Works by which the water table is likely to be lowered beyond 1 meter below natural ground surface
4	▪ Works beyond 2 meters below natural ground surface ▪ Works by which the water table is likely to be lowered beyond 2 meters below natural ground surface
5	▪ Works within 500 meters of adjacent Class 1, 2, 3 or 4 land which are likely to lower the water table below 1 meter AHD on adjacent Class 1, 2, 3 or 4 land

5.4 THE ACID SULFATE SOILS MANAGEMENT GUIDELINES (ASSMAC 1998)

The Acid Sulfate Soils Management Guidelines outline the best practice in managing the impacts of proposed works in areas likely to contain acid sulfate soils. It provides mitigation and management strategies focusing on minimising the disturbance of acid sulfate soils and to mitigate and impacts if disturbance is necessary.

This guideline forms the assessment criteria and foundation for an ASSMP if acid sulfate soils is found on site. The guidelines also outline techniques to manage extracted acid sulfate materials, remediate degraded areas affected by acid sulfate soils and advices on selecting standardised material to be applied for treatment.

5.5 THE ACID SULFATE SOILS LABORATORY METHOD GUIDELINES (ASSMAC 1998)

The Acid Sulfate Soils Laboratory Method Guidelines provides the standard methods for routine laboratory analysis of soil samples to provide information for the assessment and management of acid sulfate soils. This guideline also recommends best practice methods in the sampling, handling and transport of soil samples.

The guidelines focus on a standardised approach to routine laboratory determination of actual and potential acid production from oxidation of iron sulfides, mainly pyrite (FeS_2) in estuarine and coastal sediments. It outlines methods for acid sulfate soil related analytical work including the amount of neutralizing material required for acid sulfate soil management/treatment.

A sampling and analysis program should be designed to understand the risks of disturbing acid sulfate soils and to provide information to develop a management strategy. The level of investigation and analysis will depend on the characteristics of the site (particular site variability), the type of disturbance proposed and the sensitivity of the surrounding environment. The guidelines outline recommendation on the number of sampling sites required based on the size of the site, field analysis, sample handling, transportation and storage for all laboratory analytical works.

5.6 WASTE CLASSIFICATION

The NSW EPA Waste Classification Guidelines: Part 1 Classifying Waste (2014) is a set of guidelines used to classify waste materials for the purpose of offsite disposal. This document details a six-step procedure for determining the type of waste and the waste classification. Part of the procedure, for materials not classified as special waste or pre-classified waste, is a comparison of analytical data initially against contaminant threshold (CT) values specific to a waste category. Alternatively, the data can be assessed against specific contaminant concentration (SCC) thresholds when used in conjunction with toxicity characteristic leaching procedure (TCLP) thresholds.

All soil identified for offsite disposal requires a waste classification according to the NSW Environmental Protection Authority *Waste Classification Guidelines Part 1: Classifying Waste* (NSW EPA 2014). All acid sulfate soils must satisfy the disposal criteria as identified in the NSW EPA *Waste Classification Guidelines Part 4: Acid Sulfate Soils* (NSW EPA, 2014).

Testing for non-liquid waste is to include (but not limited to) a heavy metal screen (M8), Total Petroleum Hydrocarbons (TPH), BTEX, Organochlorine Pesticides (OCP), Polychlorinated Biphenyls (PCB) and Polycyclic Aromatic Hydrocarbons (PAH). Testing ratios to be advised by supervising Environmental Scientist.

6 SITE INSPECTION AND SAMPLING

6.1 CULVERT SITE INSPECTION AND SAMPLING EVENTS

SESL's Environmental Scientist Andrew Jacovides and Graduate Environmental Scientist Stuart Jamieson attended the sites of six (6) proposed culvert locations on 3/10/2018, and Andrew Jacovides attended site on 26/10/2018 to collect samples from the final two (2) proposed culvert locations. Where possible, samples were taken from the surface topsoil material and from the next horizon in the profile.

In addition to contamination analysis, acid sulfate soil screen and/or sPOCAS analysis, samples were also collected for geotechnical tests for Atterberg Limits (liquid limit, plastic limit, plasticity index and linear shrinkage) (not within the scope of this report). A summary of the samples collected as part of this investigation is provided in Table 4.

Table 4 – Summary of Samples Collected at the Site of Proposed Culverts

Sample Name	Sample Depth approx.(mm)	Sample Location Description
Culvert 1	800	Northern side of Wakehurst Parkway, within vegetation approximately 5-10 m from the road. 0-400: Brown sandy loam (topsoil) with organics 400-800: Brown sandy clay
Culvert 2	500	Southern side of Wakehurst Parkway, within bog-like area, approximately 5-10 m from the road. 0-500: Brown sandy clay (high moisture content)
Culvert 3	500	Southern side of Wakehurst Parkway, within bog-like area, approximately 5-10 m from the road. 0-500: Brown sandy clay
Culvert 4	500	Northern side of Wakehurst Parkway, within vegetation approximately 5-10 m from the road. 0-400: Brown loamy fill, with general rubbish and building wastes 400-500: Brown clayey sand
Culvert 5	500	Eastern side of Wakehurst Parkway, approximately 5 m from the road 0-300: Road base/fill 300-500: Clayey sand/sandy clay
Culvert 6	500	Western side of Wakehurst Parkway, approximately 5 m from the road 0-300: Road base/fill 300-500: Clayey sand/sandy clay
Culvert 7 – Above Retaining Wall	500	Eastern side of Wakehurst Parkway, approximately 5 m from the road. Sample collected from above the retaining wall Brown sandy clay
Culvert 8 - Midbank	500	Western side of Wakehurst Parkway, approximately 5 m from the road. Sample taken from halfway down the creek bank. Brown clayey sand
Culvert 9	500	Collected from the mid-bank adjacent to the existing culvert (western side). 0-300: Dark brown organic matter 0-500: Highly organic grey sandy clay

Culvert 10	500	Collected from the mid-bank adjacent to the existing culvert (eastern side). 0-300: Dark brown organic matter 0-500: Highly organic grey sandy clay
Culvert 11	300 - 700	Southern side of Wakehurst Parkway, halfway down embankment 5-10 m from the road 0-400: brown highly organic loam 400-700: Organic sandy clay/clayey sand
Culvert 12	300 - 700	Northern side of Wakehurst Parkway, halfway down embankment 5-10 m from the road 0-400: brown highly organic loam 400-700: Organic sandy clay/clayey sand

6.2 THE BENDS – MIDDLE CREEK INSPECTION

SESL's Environmental Scientist Andrew Jacovides and Graduate Environmental Scientist Stuart Jamieson conducted site inspection and sampling of the subject section of Middle Creek on 31/10/2018. Boreholes were constructed utilising hand equipment (hand auger) within the areas observed to be subject to sediment build-up, systematically along the accessible section of the creek. Boreholes were constructed for the purpose of soil profile inspection and sampling. Samples were collected within different soil horizons for the purpose of laboratory analysis (contamination screening and acid sulfate soils presence determination). Access was unavailable on the western side of the proposed investigation area, due to the presence of significant vegetation.

A summary of the soil profile observations is provided in Table 5

Table 5 – Summary of Samples Collected within the Subject Section of Middle Creek

Sample Name	Sample Depth approx.(mm)	Soil Profile Description
BH1	0-200 500-600 800-900	0-700: White/yellow course sand 700-900 Dark brown sandy loam
BH2	0-200 500-600 1100-1200	0-200: Course sand with significant organics 200-800: Course Sand 800-1200: Loamy sand
BH3	0-200 200-300 800-900	0-250: Course sand 250-300: Brown sandy loam 300-10000: Course sand
BH4	0-200 300-400 500-700	0-500: Course sand 500-800: Dark brown sandy clay loam
BH5	0-200 500-600 700-800	0-700: Course sand with minor loam inclusions 700-800: Dark brown sandy clay loam, plastic inclusions
BH6	0-200 300-400 550-700	0-550: Course sand with minor loam inclusions 550-700: Dark brown sandy clay loam

BH7	0-200 400-600 800-1000	0-600: course sand with minor loam inclusions 600-1000: dark brown sandy clay loam

7 LABORATORY ASSESSMENT

7.1 ACID SULFATE SOIL ASSESSMENT

Assessment of acid sulfate soil conditions and the impacts of the proposed development are based on information provided in the Acid Sulfate Soil Assessment Guidelines presented in the ASSMAC *Acid Sulfate Soil Manual* (1998). The guidelines include information on assessment of the likelihood that the site lies within an acid sulfate soil area, the need for an acid sulfate soil management plan, and the development of mitigation methods for the proposed development.

In order to assess the presence of actual or potential acid sulfate soil, soil samples are screened for pH. Samples were obtained in relation to soil horizon change, the presence of odour or acid sulfate soil colouration.

In the event that the pH screens results indicate potential PASS or AASS, Suspended Peroxide Oxidation-Combined Acidity and Sulfate (sPOCAS) is to be undertaken to confirm the actual acidity and sulfur trail of the material.

The laboratory results are to be compared to the “action criteria” presented in the Acid Sulfate Soil Manual (ASSMAC, 1998). These “action criteria” define the need to prepare a management plan and are based on the percentage of oxidisable sulfur (or equivalent Total Potential Acidity) for broad categories of soil types.

Table 6 – Action criteria based on ASS soil analysis for three broad texture categories

Type of Material		**Action Criteria 1–1000 tonnes ASS disturbed**		**Action Criteria if more than 1000 tonnes disturbed**	
Texture range. McDonald et al. (1990)	**Approx. clay content** ***(%<0.02mm)***	**Sulfur trail** ***% S oxidisable (oven-dry basis) e.g. S_{TOS} or S_{POS}***	**Acid trail** ***mol H^+/tonne (oven-dry basis) e.g. TPA of TSA***	**Sulfur trail** ***% S oxidisable (oven-dry basis) e.g. S_{TOS} or S_{POS}***	**Acid trail** ***mol H+/tonne (oven-dry basis) e.g. TPA of TSA***
Coarse Texture Sands to loamy sands	≤5	**0.03**	**18**	0.03	18
Medium Texture **Sandy loams to light clays**	5 - 40	0.06	36	0.03	18
Fine Texture **Medium to heavy clays and silty clays**	≥40	0.1	62	0.03	18

(ASSMAC 1998) **BOLD** – indicates adopted criteria

The “action criteria” for coarse textured soils (sands to loamy sands) has been adopted for this assessment based on the loamy sands encountered on site.

Levels of oxidisable sulfur within a soil or sediment indicate the risk to the environment on disturbance of the soils. For soils with results greater than the "action criteria" a soil management plan must be developed to manage the potential harm to the environment.

7.2 CONTAMINATION ASSESSMENT

The analysis of soil samples was undertaken against the criteria outlined in the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)*. The samples taken from the surface material underwent an acid sulfate screen and were analysed for the following chemical attributes:

- Heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni and Zn);
- Polycyclic aromatic hydrocarbons (PAH);
- Total petroleum hydrocarbons C_6 to C_{36} (TPH);
- Benzene, Toluene, Ethylbenzene and Xylenes (BTEX);
- Organochlorine Pesticides (OCP); and
- Polychlorinated Biphenyls (PCB).

8 RESULTS

8.1 ACID SULFATE SOIL ASSESSMENT - CULVERTS

Soils within the investigation consist of a range of materials in the upper profile depending on their location, including topsoil, fill material, boggy material with high organics. The lower profile overall was more consistent between sample locations, predominantly consisting of either a sandy clay or clayey sand. Bricks, concrete, plastic, demolition waste and general rubbish was found at several locations.

Samples were collected on either side of each of the six (6) proposed culvert locations, with near surface and subsurface samples collected at each location. A summary of the screen results is provided in **Error! Reference source not found.** (See Appendix C for SESL results summary).

Table 7 - Summary of Acid Sulfate Screens at Culverts.

Location (Sample depth)	Soil Description	pH H_2O	pH H_2O_2
Culvert 1 0 – 100mm	Dark Brown topsoil	6.63	3.97
Culvert 3 Surface	Dark brown boggy material with heavy vegetation on top	5.75	2.64
Culvert 4 Surface	Dark brown fill with bricks, rubbish and demo waste nearby	7.04	4.24
Culvert 5 Surface	Dark brown road base fill	7.57	5.28
Culvert 6 Surface	Dark brown road base fill	6.79	3.58
Culvert 7 Creek Sediment	Sand with organics on riverbed	6.51	3.06
Culvert 9 Surface	Black organic sandy sediment with lots of roots	3.86	2.12
Culvert 10 Surface	Black organic sandy sediment with lots of roots	5.8	2.8

Note:
H_2O denotes water
H_2O_2 denotes hydrogen peroxide

Eighteen samples were collected from the inlet and outlet locations of six (6) proposed culverts along the investigation area. Twelve (12) samples from the lower profile were analysed using sPOCAS methodology. Samples were collected and observations were recorded. **Error! Reference source not found.**Outlines of the results of the sPOCAS analysis conducted are shown in Table 5 and Appendix C: SESL Results Summary.

Table 8 – Summary of sPOCAS Test Results at Culverts

Location (Sample depth)	Soil Description	pH_{KCl}	pH_{FOX}	TAA H^+/tonne	TPA H^+/tonne	TSA H^+/tonne	S_{pos} %	Lime Requirement (kg $CaCO^3$/t)
Culvert 1 800mm	Brown sandy clay	7.0	5.6	<2	**62**	**62**	0.029	4
Culvert 2 500mm	Wet dark brown sandy clay	**4.3**	**3.4**	**147**	**496**	**349**	**0.186**	21
Culvert 3 500mm	Sandy clay	6.0	6.0	6	**55**	**49**	<0.020	<1
Culvert 4 500mm	Clayey sand	**4.7**	**4.4**	**38**	**112**	**74**	<0.020	3
Culvert 5 500mm	Clayey sand/ sandy clay	6.2	6.1	6	**35**	**29**	<0.020	<1
Culvert 6 500mm	Clayey sand/ sandy clay	5.4	**4.9**	16	**84**	**68**	<0.020	1
Culvert 7 Above Retaining Wall	Brown clayey sand	6.0	6.9	5	<2	<2	<0.020	<1
Culvert 8 Midbank	Brown clayey sand	5.9	**4.4**	13	**167**	**153**	**0.093**	5
Culvert 9 Surface	Black organic sandy sediment with lots of roots	5.6	**3.6**	<2	**28**	**27**	**0.039**	2
Culvert 9 500mm	Grey sandy clay, sulfidic odour	6.1	6.7	7	<2	<2	0.027	2
Culvert 10 500mm	Sandy organic sediment	5.9	**3.6**	3	**92**	**89**	<0.020	<1
Culvert 11 300–700mm	Organic sandy clay/clayey sand	5.0	**3.5**	**24**	**28**	4	**0.043**	4
Culvert 12 300-700mm	Organic sandy clay/clayey sand	**4.8**	**3.9**	**25**	**40**	15	<0.020	2

Values exceeding action criteria are identified in **Bold Underlined**
Action criteria are defined as:
Coarse textured soil
pH = <5
%Spos = >0.03
TAA/TSA/TPA = > 18mol H^+/tonne

Eight of the thirteen samples analysed by sPOCAS methodology exceed the action criteria for pH after oxidation. Four out of thirteen samples had titratable actual acidity above the guidelines with seven additional samples above the detection limit. Eleven samples exceeded the recommended levels for titratable peroxide acidity, and nine also had readings for titratable sulfidic acidity exceeding the action criteria and an additional two samples above the detection limit. Sulfur was above the action the limit of reporting in six samples (S_{pos}) and with four exceeding the action criteria. Other organics may also be present in samples and may contribute to the low pH values when the sample is oxidised. Therefore, based on the results, site soils encountered during this investigation consist of sandy loams, clayey sands, sand and clay and should be considered actual (AASS) and potential (PASS) acid sulfate soil and will require treatment as per an Acid Sulfate Soil Management Plan.

Required liming rates varied significantly, with up to 21 kg lime / tonne required for the soils at Culvert 2. Methodology to the management of acid sulfate soils must be prepared in a site-specific acid sulfate soil management plan.

8.2 CONTAMINATION ASSESSMENT - CULVERTS

The analysis of soil samples was undertaken against the criteria outlined in the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)*. The samples taken from the surface material underwent an acid sulfate screen and were analysed for the following chemical attributes:

- Heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni and Zn);
- Polycyclic aromatic hydrocarbons (PAH);
- Total petroleum hydrocarbons C_6 to C_{36} (TPH);
- Benzene, Toluene, Ethylbenzene and Xylenes (BTEX);
- Organochlorine Pesticides (OCP); and
- Polychlorinated Biphenyls (PCB).

Environmental sampling was performed under the following procedure:

- Decontamination of all sampling equipment between sampling and use of disposable equipment (i.e. gloves);
- Labeling of sampling containers with individual and unique identification; and
- Controlled under chain of custody procedures.

The results were compared to the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)* to determine an appropriate waste classification for the offsite disposal of the subject materials. One or more contaminants were elevated above the threshold for General Solid Waste (GSW) in six (6) of the twelve samples assessed, prior to TCLP analysis. Elevated contaminants included benzo(a)pyrene, lead and nickel.

Samples exceeding the threshold for GSW underwent Toxicity Characteristic Leaching Procedure (TCLP) in order to attempt to reduce the severity of the waste classification. These samples were found to be within the criteria for **General Solid Waste** in accordance with the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014).* In accordance with landfill's Environmental Protection Licences (EPL), the materials are **not** considered suitable for recycling. Refer to Figure 1 for sample locations.

All samples analysed for contaminants were collected from near surface soils, as these soils are the most likely to be impacted.

8.3 ACID SULFATE SOIL ASSESSMENT – THE BENDS

Samples were collected from the creek bank sediment within the subject area of Middle Creek ("The Bends" investigation area), see Figure 1. Three samples were collected from each of the sampling locations (boreholes). A single sample (the most likely to be acid sulfate soil, based on site observations) from each borehole was analysed for the sPOCAS suite, while each of the remaining samples were subject to acid sulfate screen analysis to determine potential risk of acid sulfate soil. A summary of the acid sulfate screen results for these samples is provided in Table 9.

Table 9 – Summary of Acid Sulfate Screens – The Bends

Location (Sample depth)	Soil Description	pH H_2O	pH H_2O_2
BH1 Surface	White-yellow coarse sand	6.87	3.32
BH1 800 – 900 mm	Dark brown sandy loam	6.29	2.66
BH2 0 – 200 mm	Coarse sand with organics	6.49	2.41
BH2 500 – 600 mm	Coarse sand	6.51	2.80
BH3 0 – 200 mm	Coarse sand	6.36	2.89
BH3 200 – 300 mm	Brown sandy loam lens	6.13	3.30
BH4 0 – 200 mm	Sand	6.12	2.52
BH4 500 – 700 mm	Dark brown sandy clay loam	6.03	3.21
BH5 0 – 200 mm	Coarse sand with some loam	6.16	2.70
BH5 700 – 800 mm	Dark brown sandy clay loam	5.8	2.82
BH6 0 – 200 mm	Coarse sand with some loam	6.1	2.47
BH6 550 – 700 mm	Dark brown sandy clay loam	5.79	2.90
BH7 0 – 200 mm	White-yellow coarse sand with some loam	5.88	2.34
BH7 800 – 1000 mm	Dark brown sandy clay loam	5.84	2.75

Significant drops were observed in a number of these acid sulfate screens, indicating a potential for acid sulfate soils to exist. In order to more accurately assess the potential for the subject soils to be acid sulfate, sPOCAS analysis was undertaken on eight (8) samples that showed the most significant pH drop following oxidation. A summary of these results of sPOCAS analysis is provided in Table 10.

Table 10 – Summary of sPOCAS results for The Bends

Location (Sample depth)	Soil Description	pH_{KCl}	pH_{FOX}	TAA H^+/tonne	TPA H^+/tonne	TSA H^+/tonne	S_{pos} %	Lime Requirement (kg $CaCO^3$/t)
BH1 500-600mm	White-yellow coarse sand	6.6	5.6	<2	<2	<2	0.020	<1
BH1 800-900mm	Dark brown sandy loam	**4.9**	**4.1**	17	**18**	<2	0.024	2
BH2 0-200mm	Coarse sand with organics	**4.8**	**3.3**	15	**18**	3	<0.020	1
BH2 1100-1200mm	Coarse sand with loam	5.5	**4.4**	11	<2	<2	<0.020	<1
BH3 800-900mm	Coarse sand	5.7	**4.6**	2	5	3	<0.020	<1
BH4 0-200mm	Sand	5.1	5.4	13	<2	<2	0.021	2
BH4 300-400mm	Sand	5.3	**4.4**	18	<2	<2	<0.020	1
BH5 0-200mm	Coarse sand with some loam	5.3	**4.3**	8	<2	<2	0.021	2
BH5 500-600mm	Coarse sand with some loam	5.3	**4.2**	9	<2	<2	<0.020	<1
BH6 0-200mm	Coarse sand with some loam	5.5	**4.3**	3	<2	<2	<0.020	<1
BH6 300-400mm	Coarse sand with some loam	5.3	**4.2**	11	<2	<2	<0.020	<1
BH7 0-200mm	White-yellow coarse sand with some loam	5.2	**3.4**	8	<2	<2	0.020	<1
BH7 400-600mm	White-yellow coarse sand with some loam	5.1	**4.3**	**18**	<2	<2	0.020	1

Values exceeding action criteria are identified in **Bold Underlined**
Action criteria are defined as:
Coarse textured soil
pH = <5
%Spos = >0.03
TAA/TSA/TPA = > 18mol H^+/tonne

Eleven of the thirteen samples from 'The Bends' analysed by sPOCAS methodology exceed the action criteria for pH after oxidation. One out of thirteen samples had titratable actual acidity above the action criteria with eleven additional samples above the detection limit. Two samples exceeded the action criteria for titratable peroxide acidity with an additional sample above the detection limit. Two samples had readings for titratable sulfidic acidity above the detection limit. Sulfur was present in six samples (S_{pos}), though none exceeded the action criteria threshold. Other organics may also be present in samples and may contribute to the low pH values when the sample is oxidised. Due to the absence of sulfur and very low calculated liming rate, SESL considers the sediments assessed from the subject area along Middle Creek to not be acid sulfate soils, and suggests that the minor acidity observed is the result of organic matter within the soils.

8.4 CONTAMINATION ASSESSMENT – THE BENDS

The analysis of soil samples was undertaken against the criteria outlined in the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)*. The samples taken from the surface material underwent an acid sulfate screen and were analysed for the following chemical attributes:

- Heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni and Zn);
- Polycyclic aromatic hydrocarbons (PAH);
- Total petroleum hydrocarbons C_6 to C_{36} (TPH);
- Benzene, Toluene, Ethylbenzene and Xylenes (BTEX);
- Organochlorine Pesticides (OCP); and
- Polychlorinated Biphenyls (PCB).

Environmental sampling was performed under the following procedure:

- Decontamination of all sampling equipment between sampling and use of disposable equipment (i.e. gloves);
- Labeling of sampling containers with individual and unique identification; and
- Controlled under chain of custody procedures.

The results were compared to the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014).* For all samples collected at Middle Creek at The Bends which underwent the contamination screen, analysed contaminants were found to be within the criteria for **General Solid Waste** in accordance with the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014).* In accordance with landfill's Environmental Protection Licences (EPL), the materials are **not** considered suitable for recycling. Refer to Figure 1 for sample locations.

Based on the limited assessment, SESL considers it likely that the subject soils proposed for excavation will meet the requirements for classification as Excavated Natural Material (ENM), in accordance with the NSW EPA Excavated Natural Material Order, 2014. SESL recommends that should the materials be proposed for offsite disposal, additional analysis should be undertaken to determine compliance with the ENM order, to significantly reduce the costs of offsite disposal.

9 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this assessment undertaken by SESL, the soils within the proximity of some of the proposed culvert locations are considered to be potential and actual acid sulfate soil. SESL recommends that the proposed excavation works must be managed under the site-specific Acid Sulfate Soil Management Plan (ASSMP).

Based on limited assessment and in accordance with the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)*, the soils proposed for excavation within the proximity of the culverts meet the criteria for General Solid Waste. In accordance with landfill's Environmental Protection Licenses (EPL), the material is **not** considered suitable for recycling due to elevated benzo(a)pyrene, nickel and lead.

Soils proposed for excavation within the subject area of Middle Creek (The Bends) are considered to not be Acid Sulfate Soils, and do not require management under an ASSMP. SESL suggests that the observed acidity is likely the result of extensive organic matter within the subject materials, and not the result of present sulfur.

In accordance with the *NSW EPA Waste Classification Guidelines – Part 1: Classifying Waste (2014)*, all samples collected from within creek sediments meet the criteria for General Solid Waste. However, based on the results of this limited assessment, SESL recommends that the subject soils proposed for excavation will meet the requirements for classification as Excavated Natural Material (ENM), and that consideration should be given to further assessment for the classification of these soils as ENM, to reduce the cost of offsite disposal.

This report is based on the field data obtained from the samples collected from the proposed inlet and outlet locations of six culverts in the investigation area and material collected from the subject sediments at Middle Creek (The Bends). If any materials are identified during excavation that is different to what has been described in this report, additional assessment may be required.

The principal and sub-contractors must ensure that transportation of soil materials occurs lawfully, and that the facilities to which the material is transported (whether for disposal or treatment) is appropriately licensed to receive waste materials.

10 LIMITATIONS

This report only covers the site conditions at the time of investigation. Should there be any variation in the site conditions beyond this date, such as imported fill, chemical spillage, illegal dumping, further assessment will be required.

This report is for the use of the client and any relevant authorities that rely on the information for development applications and approval processes. Any reliance on this report by third parties shall be at such parties' sole risk. This report shall only be presented in full and may not be used to support any other objective other than those set out in the report.

SESL's assessment is necessarily based on the result of limited site investigations and upon the restricted program of visual assessment of the surface and consultation of available records. Neither SESL, nor any other reputable consultant, can provide unqualified warranties nor does SESL assume any liabilities for site conditions not observed, or accessible during the time of investigations.

No site investigations can be thorough enough to provide absolute confirmation of the presence or absence of substances, which may be considered contaminating, hazardous or polluting. Similarly, the level of testing undertaken cannot be considered to unequivocally characterise the degree or extent of contamination on site. In addition, regulatory or guideline criteria for the evaluation of environmental soil and groundwater quality are frequently being reviewed and concentrations of contaminants which are considered acceptable at present may in the future be considered to exceed acceptance criteria. Similar conditions may prevail in regard to site remediation standards as different regulatory mechanisms are developed and implemented.

11 REFERENCES

Acid Sulfate Soil Planning Guidelines, NSW Acid Sulfate Soils Management Advisory Committee (1998).

Environmental Protection Authority, Assessing and Managing Acid Sulfate Soils – Guidelines for Management in NSW Coastal Area, 1995).

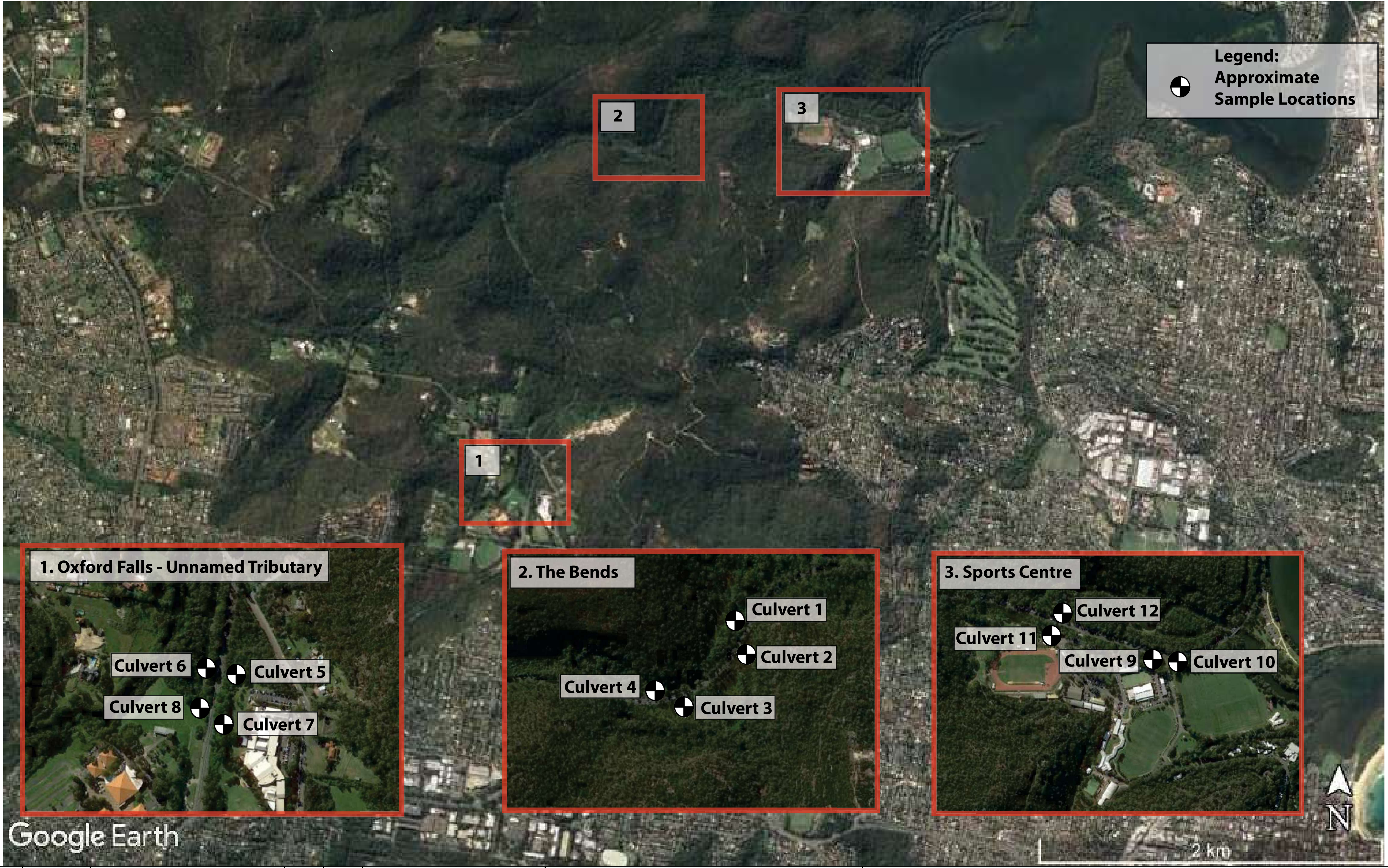
Chapman GA and Murphy CL, 1989, Soil Landscapes of the Sydney 1:100,000 Sheet report, Department of Conservation and Land Management, Sydney.

UPSS Regulation Sensitive Zone Map for Warringah Council, Department of Environment, Climate Change and Water (NSW 2010).

Waste Classification Guidelines Part 1: Classifying Waste, NSW Environmental Protection Authority (NSW EPA, 2014).

Waste Classification Guidelines Part 4: Acid Sulfate Soils, Department of Environment and Climate Change (NSW 2014).

Appendix A



01	1/11/2018	First draft - Sampling map locations	SJ	RJ
VER	DATE	AMENDMENTS	DRW	CKD

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ATTACHMENT A

Map 1: Site location and sampling map

Project Ref:	J001187
Project:	Wakehurst Parkway Flood Mitigation Acid Sulfate and Contamination Assessment
Location:	Wakehurst Parkway, North Narrabeen NSW 2101
Client:	Northern Beaches Council
GPS Coordinates:	33˚43'00" S 151˚16'00" E
PRINT:	A3 (P)

01	4/12/2018	First draft - Sampling map locations	SJ	KL
VER	DATE	AMENDMENTS	DRW	CKD

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ATTACHMENT A

Map 2: The Bends sampling map

Project Ref:	J001187
Project:	Wakehurst Parkway Flood Mitigation Acid Sulfate and Contamination Assessment
Location:	Wakehurst Parkway, North Narrabeen NSW 2101
Client:	Northern Beaches Council
GPS Coordinates:	33°43'00" S 151°15'00" E
PRINT:	A3 (P)

Appendix B

Warringah Local Environmental Plan 2011

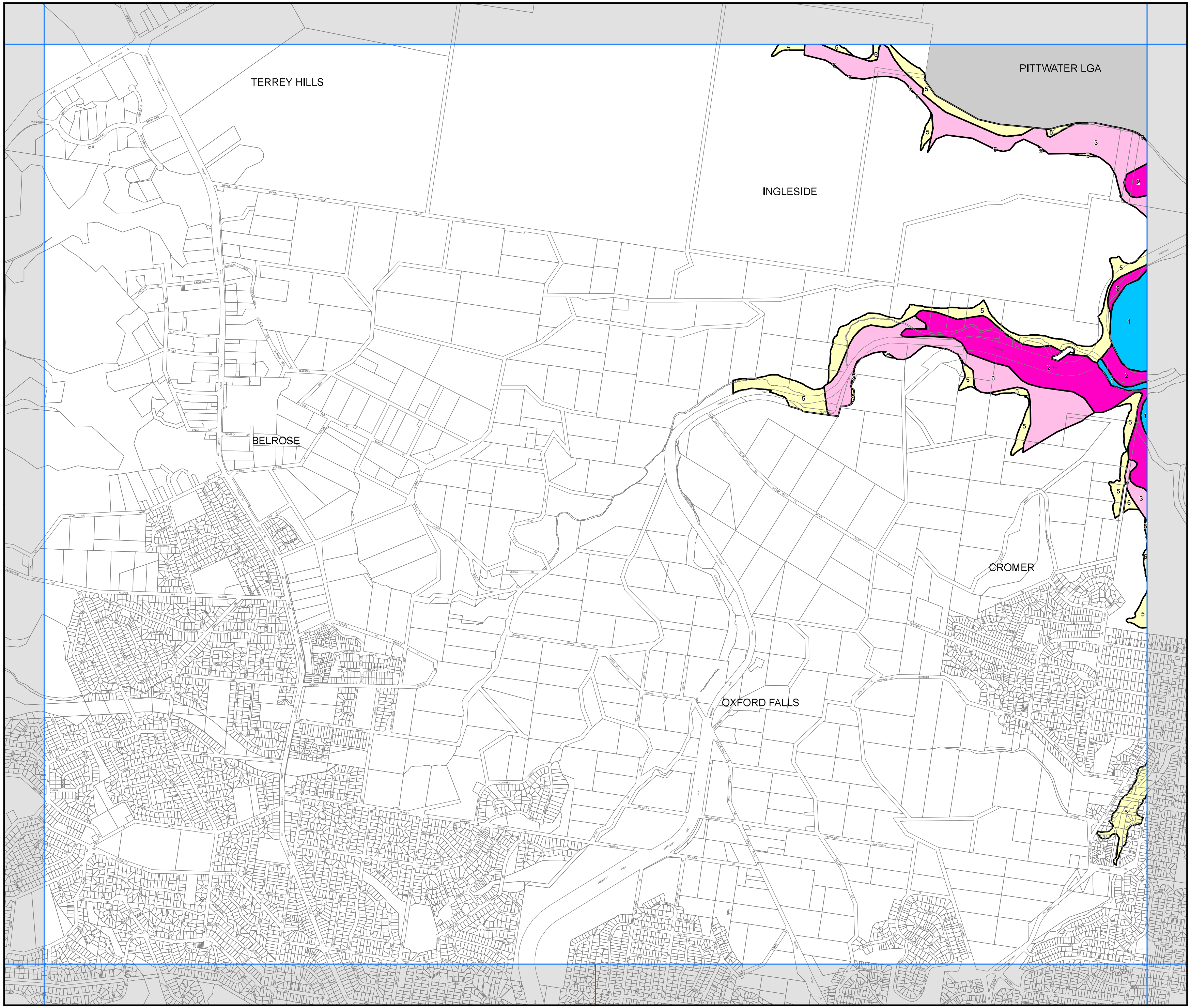
Acid Sulfate Soils Map - Sheet ASS_007

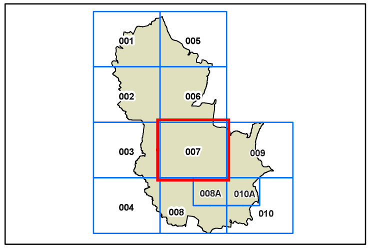
Acid Sulfate Soils

- 1 Class 1
- 2 Class 2
- 3 Class 3
- 4 Class 4
- 5 Class 5

Cadastre

- ☐ Cadastre 19/09/2011 © Warringah Council





N

0 200 400 Metres

Scale: 1:20,000 @ A3

Projection: GDA 1994
Zone 56

Map identification number: 1800_COM_ASS_007_020_20111117

Appendix C

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Multiple Analysis Profile

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Web: www.sesl.com.au

Batch N°: 49927 **Sample N°: 1** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 1 0-100**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.63
pH H_2O_2	pH units	3.97
Colour	-	10YR 2/2 Very Dark Brown
Colour Change	-	Greenish Yellow
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Consultant:

Andrew Jacovides

Authorised Signatory:

Date Report Generated
7/11/2018

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Batch N°: 49927 **Sample N°: 4** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 3 Surface**
Description: **Soil**
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	5.75
pH H_2O_2	pH units	2.64
Colour	-	10YR 2/2 Very Dark Brown
Colour Change	-	Greenish Yellow
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Consultant:

Andrew Jacovides

Authorised Signatory:

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Batch N°: 49927 **Sample N°: 6** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 4 Surface**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	7.04
pH H_2O_2	pH units	4.24
Colour	-	10YR 2/2 Very Dark Brown
Colour Change	-	Greenish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

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Batch N°: 49927 **Sample N°: 8** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 5 Surface**
Description: **Soil**
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	7.57
pH H_2O_2	pH units	5.28
Colour	-	10YR 2/2 Very Dark Brown
Colour Change	-	-
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

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Batch N°: 49927 **Sample N°: 10** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 6 Surface**
Description: **Soil**
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.79
pH H_2O_2	pH units	3.58
Colour	-	10YR 3/3 Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Consultant:

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Batch N°: 49927 **Sample N°: 12** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 7 Creek Sediment**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.51
pH H_2O_2	pH units	3.06
Colour	-	2.5Y 3/3 Dark Olive Brown
Colour Change	-	Greenish Yellow
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

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Batch N°: 49927 **Sample N°: 15** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 9 Surface**
Description: **Soil**
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	3.86
pH H_2O_2	pH units	2.12
Colour	-	10YR 2/2 Very Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

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Batch N°: 49927 **Sample N°: 17** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 10 Surface**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC, ASS1**

Analysis	Units	Result
pH H_2O	pH units	5.8
pH H_2O_2	pH units	2.8
Colour	-	10YR 2/2 Very Dark Brown
Colour Change	-	Greenish Yellow
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

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Batch N°: 50296 **Sample N°: 1** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH1 Surface**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.87
pH H_2O_2	pH units	3.32
Colour	-	10YR 5/4 Yellowish Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Slight reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

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Multiple Analysis Profile

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Batch N°: 50296 **Sample N°: 3** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH1 800 - 900**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.29
pH H_2O_2	pH units	2.66
Colour	-	10YR 3/2 Very Dark Grayish Bro
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	High reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

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Authorised Signatory:

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5/12/2018

Multiple Analysis Profile

Sample Drop Off: 16 Chilvers Road
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Batch N°: 50296 **Sample N°: 4** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH2 0 - 200**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.49
pH H_2O_2	pH units	2.41
Colour	-	10YR 4/3 Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

Date Report Generated
5/12/2018

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Batch N°: 50296 **Sample N°: 5** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **BH2 500 - 600**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.51
pH H_2O_2	pH units	2.8
Colour	-	10YR 4/3 Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

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Batch N°: 50296 **Sample N°: 7** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **BH3 0 - 200**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.36
pH H_2O_2	pH units	2.89
Colour	-	10YR 4/3 Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Coarse Root Material

Consultant:

Authorised Signatory:

Date Report Generated
5/12/2018

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Multiple Analysis Profile

Sample Drop Off: 16 Chilvers Road
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Batch N°: 50296 **Sample N°: 8** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**

SESL Quote N°:

Client Contact: **Fiona Coe**

Sample Name: **BH3 200 - 300**

Client Order N°:

Description: **Soil**

Address:

Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.13
pH H_2O_2	pH units	3.3
Colour	-	10YR 3/3 Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	High reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

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Authorised Signatory:

Date Report Generated
5/12/2018

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Batch N°: 50296 **Sample N°: 10** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH4 0 - 200**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.12
pH H_2O_2	pH units	2.52
Colour	-	10YR 3/3 Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

Date Report Generated
5/12/2018

Multiple Analysis Profile

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Batch N°: 50296 **Sample N°: 12** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **BH4 500 - 700**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.03
pH H_2O_2	pH units	3.21
Colour	-	10YR 3/2 Very Dark Grayish Bro
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	High reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

Date Report Generated
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Multiple Analysis Profile

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Batch N°: 50296 **Sample N°: 13** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH5 0 - 200**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.16
pH H_2O_2	pH units	2.7
Colour	-	10YR 3/3 Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

Date Report Generated
5/12/2018

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Multiple Analysis Profile

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Batch N°: 50296 **Sample N°: 15** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH5 700 - 800**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	5.8
pH H_2O_2	pH units	2.82
Colour	-	10YR 3/2 Very Dark Grayish Bro
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	High reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

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Multiple Analysis Profile

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Batch N°: 50296 **Sample N°: 16** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH6 0 - 200**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	6.1
pH H_2O_2	pH units	2.47
Colour	-	10YR 3/3 Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

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Batch N°: 50296 **Sample N°: 18** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **BH6 550 - 700**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	5.79
pH H_2O_2	pH units	2.9
Colour	-	10YR 3/2 Very Dark Grayish Bro
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	High reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

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Multiple Analysis Profile

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Batch N°: 50296 **Sample N°: 19** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH7 0 - 200**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	5.88
pH H_2O_2	pH units	2.34
Colour	-	10YR 3/3 Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	Moderate reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

Date Report Generated
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Batch N°: 50296 **Sample N°: 21** **Date Instructions Received: 1/11/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **BH7 800 - 1000**
Description: **Soil**
Test Type: **BWC_EXT, ASS1**

Analysis	Units	Result
pH H_2O	pH units	5.84
pH H_2O_2	pH units	2.75
Colour	-	10YR 3/3 Dark Brown
Colour Change	-	Yellowish
Effervescence Type	-	Frothing
Effervescence Strength	-	High reaction
Shellgrit/Carbonates	-	Nil Present
Odour	-	Nil Detected
Pyrite/Jarosite	-	Nil Visible
Organic Matter	-	Fine Root Material

Consultant:

Andrew Jacovides

Authorised Signatory:

Date Report Generated
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Batch N°: 49927 **Sample N°: 2** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 1 800**
Description: **Soil**
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, PSD - 4.75**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	7.0	
pH OX (23B)	pH units	5.6	
Titratable Actual Acidity (23F)	moles H+/T	<2	
Titratable Peroxide Acidity (23G)	moles H+/T	62	
Titratable Sulfidic Acidity (23H)	moles H+/T	62	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	<0.020	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	0.100	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	0.100	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	0.029	
Peroxide Oxidisable Sulfur (23E)	% S	0.029	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	18	
KCl Extractable Calcium (23Vh)	% Ca	0.102	
Peroxide Calcium (23Wh)	% Ca	0.110	
Acid Reacted Calcium (23X)	% Ca	<0.020	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	<10	
sulfidic - Acid Reacted Calcium (s-23X)	% S	<0.020	
KCl Extractable Magnesium (23Sm)	% Mg	<0.020	
Peroxide Magnesium (23Tm)	% Mg	0.026	
Acid Reacted Magnesium (23U)	% Mg	0.026	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	21	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	0.034	
Excess Acid Neutralising Capacity (23Q)	% CaCO3		
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T		
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S		
HCl Extractable Sulfur (20Be)	% S		
Net Acid Soluble Sulfur (20Je)	% S		
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T		
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S		
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	0.08	
Net Acidity (acidity units)	moles H+/T	47	
Liming Rate	kg CaCO3/t	4	
Net Acidity excluding ANC (sulfur units)	% S	0.08	
Net Acidity excluding ANC (acidity units)	mole H+ / t	47	
Liming Rate excluding ANC	kg CaCO3/t	4	

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Batch N°: 49927 **Sample N°: 2** **Date Instructions Received: 5/10/18** **Report Status:** ○ **Preliminary** ○

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 1 800**
Client Order N°:
Description: **Soil**
Address:
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, PSD - 4.75**

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Date Report Generated
7/11/2018

Consultant

Andrew Jacovides

Authorised Signatory

Method References:
SESL Method PM0011: Analysis of acid sulphate soils - sPOCAS derived from Ahern CR, Blunden B and Stone Y (eds.) (1998). *Acid Sulphate Soils Laboratory Methods* Guidelines Published by the Acid Sulphate Soil Management Advisory committe, Wollongbar, NSW, Australia

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Batch N°: 49927 **Sample N°: 3** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 2**
Description: **Soil**
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, PSD - 4.75, BWC, CBR_RL**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	4.3	
pH OX (23B)	pH units	3.4	
Titratable Actual Acidity (23F)	moles H+/T	147	
Titratable Peroxide Acidity (23G)	moles H+/T	496	
Titratable Sulfidic Acidity (23H)	moles H+/T	349	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.236	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	0.795	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	0.560	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	0.186	
Peroxide Oxidisable Sulfur (23E)	% S	0.186	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	116	
KCl Extractable Calcium (23Vh)	% Ca	0.109	
Peroxide Calcium (23Wh)	% Ca	0.116	
Acid Reacted Calcium (23X)	% Ca	<0.020	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	<10	
sulfidic - Acid Reacted Calcium (s-23X)	% S	<0.020	
KCl Extractable Magnesium (23Sm)	% Mg	0.044	
Peroxide Magnesium (23Tm)	% Mg	0.054	
Acid Reacted Magnesium (23U)	% Mg	<0.020	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	<10	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	<0.020	
Excess Acid Neutralising Capacity (23Q)	% CaCO3		
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T		
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S		
HCl Extractable Sulfur (20Be)	% S	0.035	
Net Acid Soluble Sulfur (20Je)	% S	0.035	
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T	16	
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S	0.026	
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	0.45	
Net Acidity (acidity units)	moles H+/T	279	
Liming Rate	kg CaCO3/t	21	
Net Acidity excluding ANC (sulfur units)	% S	0.45	
Net Acidity excluding ANC (acidity units)	mole H+ / t	279	
Liming Rate excluding ANC	kg CaCO3/t	21	

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Batch N°: 49927 **Sample N°: 3** **Date Instructions Received: 5/10/18** **Report Status:** ○ **Preliminary** ○

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 2**
Description: **Soil**
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, PSD - 4.75, BWC, CBR_RL**

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Date Report Generated
7/11/2018

Consultant

Andrew Jacovides

Authorised Signatory

Method References:
SESL Method PM0011: Analysis of acid sulphate soils - sPOCAS derived from Ahern CR, Blunden B and Stone Y (eds.) (1998). *Acid Sulphate Soils Laboratory Methods* Guidelines Published by the Acid Sulphate Soil Management Advisory committe, Wollongbar, NSW, Australia

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Batch N°: 49927 **Sample N°: 5** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 3 500**
Description: **Soil**
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	6.0	
pH OX (23B)	pH units	6.0	
Titratable Actual Acidity (23F)	moles H+/T	6	
Titratable Peroxide Acidity (23G)	moles H+/T	55	
Titratable Sulfidic Acidity (23H)	moles H+/T	49	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	<0.020	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	0.088	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	0.078	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	<0.020	
Peroxide Oxidisable Sulfur (23E)	% S	<0.020	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	<10	
KCl Extractable Calcium (23Vh)	% Ca	0.116	
Peroxide Calcium (23Wh)	% Ca	0.121	
Acid Reacted Calcium (23X)	% Ca	<0.020	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	<10	
sulfidic - Acid Reacted Calcium (s-23X)	% S	<0.020	
KCl Extractable Magnesium (23Sm)	% Mg	<0.020	
Peroxide Magnesium (23Tm)	% Mg	<0.020	
Acid Reacted Magnesium (23U)	% Mg	<0.020	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	<10	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	<0.020	
Excess Acid Neutralising Capacity (23Q)	% CaCO3		
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T		
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S		
HCl Extractable Sulfur (20Be)	% S		
Net Acid Soluble Sulfur (20Je)	% S		
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T		
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S		
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	<0.02	
Net Acidity (acidity units)	moles H+/T	<10	
Liming Rate	kg CaCO3/t	<1	
Net Acidity excluding ANC (sulfur units)	% S	<0.02	
Net Acidity excluding ANC (acidity units)	mole H+ / t	<10	
Liming Rate excluding ANC	kg CaCO3/t	<1	

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Batch N°: 49927 **Sample N°: 5** **Date Instructions Received: 5/10/18** **Report Status:** ○ **Preliminary** ○

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 3 500**
Description: **Soil**
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Date Report Generated
7/11/2018

Consultant

Andrew Jacovides

Authorised Signatory

Method References:
SESL Method PM0011: Analysis of acid sulphate soils - sPOCAS derived from Ahern CR, Blunden B and Stone Y (eds.) (1998). *Acid Sulphate Soils Laboratory Methods* Guidelines Published by the Acid Sulphate Soil Management Advisory committe, Wollongbar, NSW, Australia

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Batch N°: 49927 **Sample N°: 7** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 4 500**
Client Order N°:
Description: **Soil**
Address:
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	4.7	
pH OX (23B)	pH units	4.4	
Titratable Actual Acidity (23F)	moles H+/T	38	
Titratable Peroxide Acidity (23G)	moles H+/T	112	
Titratable Sulfidic Acidity (23H)	moles H+/T	74	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.061	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	0.179	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	0.118	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	<0.020	
Peroxide Oxidisable Sulfur (23E)	% S	<0.020	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	<10	
KCl Extractable Calcium (23Vh)	% Ca	0.042	
Peroxide Calcium (23Wh)	% Ca	0.048	
Acid Reacted Calcium (23X)	% Ca	<0.020	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	<10	
sulfidic - Acid Reacted Calcium (s-23X)	% S	<0.020	
KCl Extractable Magnesium (23Sm)	% Mg	<0.020	
Peroxide Magnesium (23Tm)	% Mg	<0.020	
Acid Reacted Magnesium (23U)	% Mg	<0.020	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	<10	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	<0.020	
Excess Acid Neutralising Capacity (23Q)	% CaCO3		
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T		
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S		
HCl Extractable Sulfur (20Be)	% S		
Net Acid Soluble Sulfur (20Je)	% S		
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T		
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S		
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	0.06	
Net Acidity (acidity units)	moles H+/T	38	
Liming Rate	kg CaCO3/t	3	
Net Acidity excluding ANC (sulfur units)	% S	0.06	
Net Acidity excluding ANC (acidity units)	mole H+ / t	38	
Liming Rate excluding ANC	kg CaCO3/t	3	

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Batch N°: 49927 **Sample N°: 7** **Date Instructions Received: 5/10/18** **Report Status:** ○ **Preliminary** ○

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 4 500**
Client Order N°:
Description: **Soil**
Address:
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Date Report Generated
7/11/2018

Consultant
Andrew Jacovides

Authorised Signatory

Method References:
SESL Method PM0011: Analysis of acid sulphate soils - sPOCAS derived from Ahern CR, Blunden B and Stone Y (eds.) (1998). *Acid Sulphate Soils Laboratory Methods* Guidelines Published by the Acid Sulphate Soil Management Advisory committe, Wollongbar, NSW, Australia

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Batch N°: 49927 **Sample N°: 9** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 5 500**
Client Order N°:
Description: **Soil**
Address:
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	6.2	
pH OX (23B)	pH units	6.1	
Titratable Actual Acidity (23F)	moles H+/T	6	
Titratable Peroxide Acidity (23G)	moles H+/T	35	
Titratable Sulfidic Acidity (23H)	moles H+/T	29	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	<0.020	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	0.056	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	0.047	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	<0.020	
Peroxide Oxidisable Sulfur (23E)	% S	<0.020	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	<10	
KCl Extractable Calcium (23Vh)	% Ca	0.104	
Peroxide Calcium (23Wh)	% Ca	0.126	
Acid Reacted Calcium (23X)	% Ca	0.022	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	11	
sulfidic - Acid Reacted Calcium (s-23X)	% S	<0.020	
KCl Extractable Magnesium (23Sm)	% Mg	<0.020	
Peroxide Magnesium (23Tm)	% Mg	0.021	
Acid Reacted Magnesium (23U)	% Mg	0.021	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	18	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	0.028	
Excess Acid Neutralising Capacity (23Q)	% CaCO3		
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T		
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S		
HCl Extractable Sulfur (20Be)	% S		
Net Acid Soluble Sulfur (20Je)	% S		
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T		
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S		
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	<0.02	
Net Acidity (acidity units)	moles H+/T	<10	
Liming Rate	kg CaCO3/t	<1	
Net Acidity excluding ANC (sulfur units)	% S	<0.02	
Net Acidity excluding ANC (acidity units)	mole H+ / t	<10	
Liming Rate excluding ANC	kg CaCO3/t	<1	

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Batch N°: 49927 **Sample N°: 9** **Date Instructions Received: 5/10/18** **Report Status:** ○ **Preliminary** ○

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 5 500**
Description: **Soil**
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Date Report Generated
7/11/2018

Consultant

Andrew Jacovides

Authorised Signatory

Method References:
SESL Method PM0011: Analysis of acid sulphate soils - sPOCAS derived from Ahern CR, Blunden B and Stone Y (eds.) (1998). *Acid Sulphate Soils Laboratory Methods* Guidelines Published by the Acid Sulphate Soil Management Advisory committe, Wollongbar, NSW, Australia

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Batch N°: 49927 **Sample N°: 11** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 6 500**
Client Order N°:
Description: **Soil**
Address:
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	5.4	
pH OX (23B)	pH units	4.9	
Titratable Actual Acidity (23F)	moles H+/T	16	
Titratable Peroxide Acidity (23G)	moles H+/T	84	
Titratable Sulfidic Acidity (23H)	moles H+/T	68	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.025	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	0.135	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	0.109	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	<0.020	
Peroxide Oxidisable Sulfur (23E)	% S	<0.020	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	<10	
KCl Extractable Calcium (23Vh)	% Ca	0.042	
Peroxide Calcium (23Wh)	% Ca	0.052	
Acid Reacted Calcium (23X)	% Ca	<0.020	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	<10	
sulfidic - Acid Reacted Calcium (s-23X)	% S	<0.020	
KCl Extractable Magnesium (23Sm)	% Mg	<0.020	
Peroxide Magnesium (23Tm)	% Mg	<0.020	
Acid Reacted Magnesium (23U)	% Mg	<0.020	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	<10	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	<0.020	
Excess Acid Neutralising Capacity (23Q)	% CaCO3		
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T		
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S		
HCl Extractable Sulfur (20Be)	% S		
Net Acid Soluble Sulfur (20Je)	% S		
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T		
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S		
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	0.02	
Net Acidity (acidity units)	moles H+/T	16	
Liming Rate	kg CaCO3/t	1	
Net Acidity excluding ANC (sulfur units)	% S	0.02	
Net Acidity excluding ANC (acidity units)	mole H+ / t	16	
Liming Rate excluding ANC	kg CaCO3/t	1	

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Batch N°: 49927 **Sample N°: 11** **Date Instructions Received: 5/10/18** **Report Status:** ○ **Preliminary** ○

Client Name:	**Northern Beaches Council**	Project Name:	**Wakehurst Parkway Flood Mitigation Acid Sulfate and**
		SESL Quote N°:	
Client Contact:	**Fiona Coe**	Sample Name:	**Culvert 6 500**
Client Order N°:		Description:	**Soil**
Address:		Test Type:	**sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Date Report Generated
7/11/2018

Consultant

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Method References:
SESL Method PM0011: Analysis of acid sulphate soils - sPOCAS derived from Ahern CR, Blunden B and Stone Y (eds.) (1998). *Acid Sulphate Soils Laboratory Methods* Guidelines Published by the Acid Sulphate Soil Management Advisory committe, Wollongbar, NSW, Australia

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Batch N°: 49927 **Sample N°: 13** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 7 Above retaining wall**
Client Order N°:
Description: **Soil**
Address:
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	6.0	
pH OX (23B)	pH units	6.9	
Titratable Actual Acidity (23F)	moles H+/T	5	
Titratable Peroxide Acidity (23G)	moles H+/T	<2	
Titratable Sulfidic Acidity (23H)	moles H+/T	<2	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	<0.020	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	<0.020	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	<0.020	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	<0.020	
Peroxide Oxidisable Sulfur (23E)	% S	<0.020	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	<10	
KCl Extractable Calcium (23Vh)	% Ca	0.106	
Peroxide Calcium (23Wh)	% Ca	0.160	
Acid Reacted Calcium (23X)	% Ca	0.054	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	27	
sulfidic - Acid Reacted Calcium (s-23X)	% S	0.043	
KCl Extractable Magnesium (23Sm)	% Mg	<0.020	
Peroxide Magnesium (23Tm)	% Mg	0.020	
Acid Reacted Magnesium (23U)	% Mg	0.020	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	16	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	0.026	
Excess Acid Neutralising Capacity (23Q)	% CaCO3	0.207	
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T	41	
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S	0.066	
HCl Extractable Sulfur (20Be)	% S		
Net Acid Soluble Sulfur (20Je)	% S		
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T		
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S		
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	<0.02	
Net Acidity (acidity units)	moles H+/T	<10	
Liming Rate	kg CaCO3/t	<1	
Net Acidity excluding ANC (sulfur units)	% S	<0.02	
Net Acidity excluding ANC (acidity units)	mole H+ / t	<10	
Liming Rate excluding ANC	kg CaCO3/t	<1	

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Batch N°: 49927 **Sample N°: 13** **Date Instructions Received: 5/10/18** **Report Status: ○ Preliminary ○**

Client Name: **Northern Beaches Council**
Client Contact: **Fiona Coe**
Client Order N°:
Address:

Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Sample Name: **Culvert 7 Above retaining wall**
Description: **Soil**
Test Type: **sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

See report *J001187 Wakehurst Parkway Flood Mitigation - Acid Sulfate Soil and Contamination Assessment - Culverts* for commentary.

Date Report Generated
7/11/2018

Consultant

Andrew Jacovides

Authorised Signatory

Method References:
SESL Method PM0011: Analysis of acid sulphate soils - sPOCAS derived from Ahern CR, Blunden B and Stone Y (eds.) (1998). *Acid Sulphate Soils Laboratory Methods* Guidelines Published by the Acid Sulphate Soil Management Advisory committe, Wollongbar, NSW, Australia

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Batch N°: 49927 **Sample N°: 14** **Date Instructions Received: 5/10/18** **Report Status: Draft**

Client Name: **Northern Beaches Council**
Project Name: **Wakehurst Parkway Flood Mitigation Acid Sulfate and**
SESL Quote N°:
Client Contact: **Fiona Coe**
Sample Name: **Culvert 8 Midbank**
Client Order N°:
Description: **Soil**
Address:
Test Type: **BWC, sPOCAS_ALS, Atterberg Limits_RL, CBR_RL, PSD - 4.75**

Analysis	Unit	Result	Comment
pH KCl (23A)	pH units	5.9	
pH OX (23B)	pH units	4.4	
Titratable Actual Acidity (23F)	moles H+/T	13	
Titratable Peroxide Acidity (23G)	moles H+/T	167	
Titratable Sulfidic Acidity (23H)	moles H+/T	153	
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.022	
sulfidic - Titratable Peroxide Acidity (s-23G)	% pyrite S	0.268	
sulfidic - Titratable Sulfidic Acidity (s-23H)	% pyrite S	0.246	
KCl Extractable Sulfur (23Ce)	% S	<0.020	
Peroxide Sulfur (23De)	% S	0.093	
Peroxide Oxidisable Sulfur (23E)	% S	0.093	
acidity - Peroxide Oxidisable Sulfur (a-23E)	moles H+/T	58	
KCl Extractable Calcium (23Vh)	% Ca	0.082	
Peroxide Calcium (23Wh)	% Ca	0.100	
Acid Reacted Calcium (23X)	% Ca	<0.020	
acidity - Acid Reacted Calcium (a-23X)	moles H+/T	<10	
sulfidic - Acid Reacted Calcium (s-23X)	% S	<0.020	
KCl Extractable Magnesium (23Sm)	% Mg	0.068	
Peroxide Magnesium (23Tm)	% Mg	0.076	
Acid Reacted Magnesium (23U)	% Mg	<0.020	
Acidity - Acid Reacted Magnesium (a-23U)	moles H+/T	<10	
sulfidic - Acid Reacted Magnesium (s-23U)	% S	<0.020	
Excess Acid Neutralising Capacity (23Q)	% CaCO3		
acidity-Excess Acid Neutralising Capacity (a-23Q)	moles H+/T		
sulfidic-Excess Acid Neutralising Capacity (s-23Q)	% S		
HCl Extractable Sulfur (20Be)	% S		
Net Acid Soluble Sulfur (20Je)	% S		
acidity - Net Acid Soluble Sulfur (a-20J)	moles H+/T		
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S		
ANC Fineness Factor	-	1.5	
Net Acidity (sulfur units)	% S	0.11	
Net Acidity (acidity units)	moles H+/T	71	
Liming Rate	kg CaCO3/t	5	
Net Acidity excluding ANC (sulfur units)	% S	0.11	
Net Acidity excluding ANC (acidity units)	mole H+ / t	71	
Liming Rate excluding ANC	kg CaCO3/t	5	